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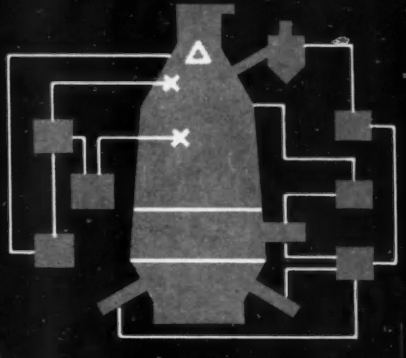
MAY 1959

# Control ENGINEERING

INSTRUMENTATION AND CONTROL SYSTEMS

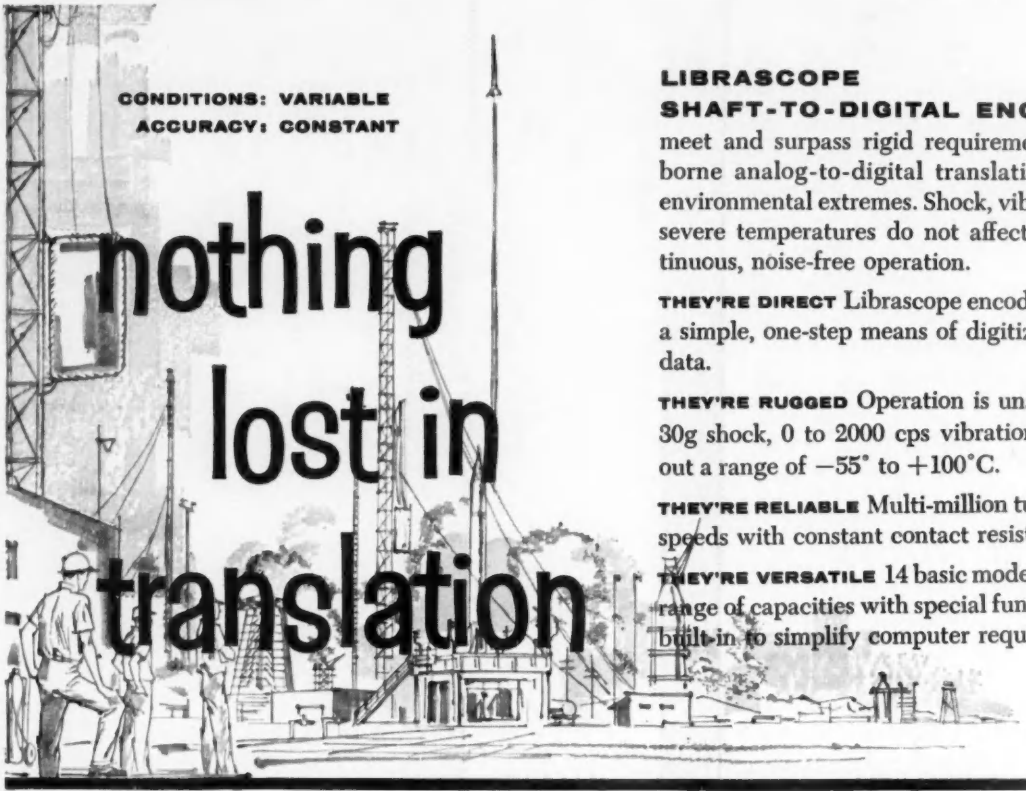
## What's New

Automatic Inspection Spots Vehicle Troubles



Soviets Push Blast Furnace Controls

Controls Turn Post Office Modern




**LIBRASCOPE SHAFT-TO-DIGITAL ENCODERS** meet and surpass rigid requirements of airborne analog-to-digital translation despite environmental extremes. Shock, vibration, and severe temperatures do not affect their continuous, noise-free operation.

**THEY'RE DIRECT** Librascope encoders provide a simple, one-step means of digitizing analog data.

**THEY'RE RUGGED** Operation is unaffected by 30g shock, 0 to 2000 cps vibration, throughout a range of −55° to +100°C.

**THEY'RE RELIABLE** Multi-million turns at high speeds with constant contact resistance.

**THEY'RE VERSATILE** 14 basic models in a wide range of capacities with special function codes built-in to simplify computer requirements.

| OUTPUT CODE | MODEL NO. ◎ | TOTAL CAPACITY | RESOLUTION PER TURN | DIMENSIONS DIA. x LENGTH |
|---|---|---|---|---|
| PARALLEL BINARY (LINEAR) | 740 | 10 bits (1024) | 1024 | 4 3/16" x 2 1/4" |
| | 743 | 13 bits (8192) | 128 | 2" x 3 15/32" |
| SERIAL BINARY (LINEAR) | 707 | 7 bits (128) | 128 | 2" x 2 25/64" |
| | 713 | 13 bits (8192) | 128 | 2" x 3 15/32" |
| | 717 | 17 bits (131,072) | 128 | 2" x 4 13/16" |
| | 719 | 19 bits (524,288) | 128 | 2" x 4 13/16" |
| SERIAL BINARY (SIN-COS) | 757† | 7 bits per quadrant* (4 quadrants) | 512 | 2 1/4" x 4 1/16" |
| | 758† | 8 bits per quadrant* (4 quadrants) | 1024 | 4 1/16" x 3 3/16" |
| BINARY CODED DECIMAL (8-4-2-1) | 723 | 2,000 | 200 | 3 1/16" x 4 27/32" |
| | 724 | 20,000 | 200 | 3 1/16" x 4 27/32" |
| | 733 | 3,600 | 200 | 3 1/16" x 4 27/32" |
| | 734 | 36,000 | 200 | 3 1/16" x 6 3/4" |
| | 735 | 360,000 | 200 | 3 1/16" x 6 3/4" |
| GRAY | 708 | 8 bits (256) | 256 | 3 1/16" x 1 11/16" |

◎All models available with internally mounted isolation diodes for sequential multiplexing applications.

†Available in hermetically sealed servo-driven package as Models 757-S and 758-S.

*Including limit 1 and polarity information. Sine and cosine functions generated simultaneously and independently. One turn of shaft generates 4 quadrants of information.

*For full details* on Librascope shaft-to-digital encoders write for catalog E 11-1.

L19-1

0001
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0011
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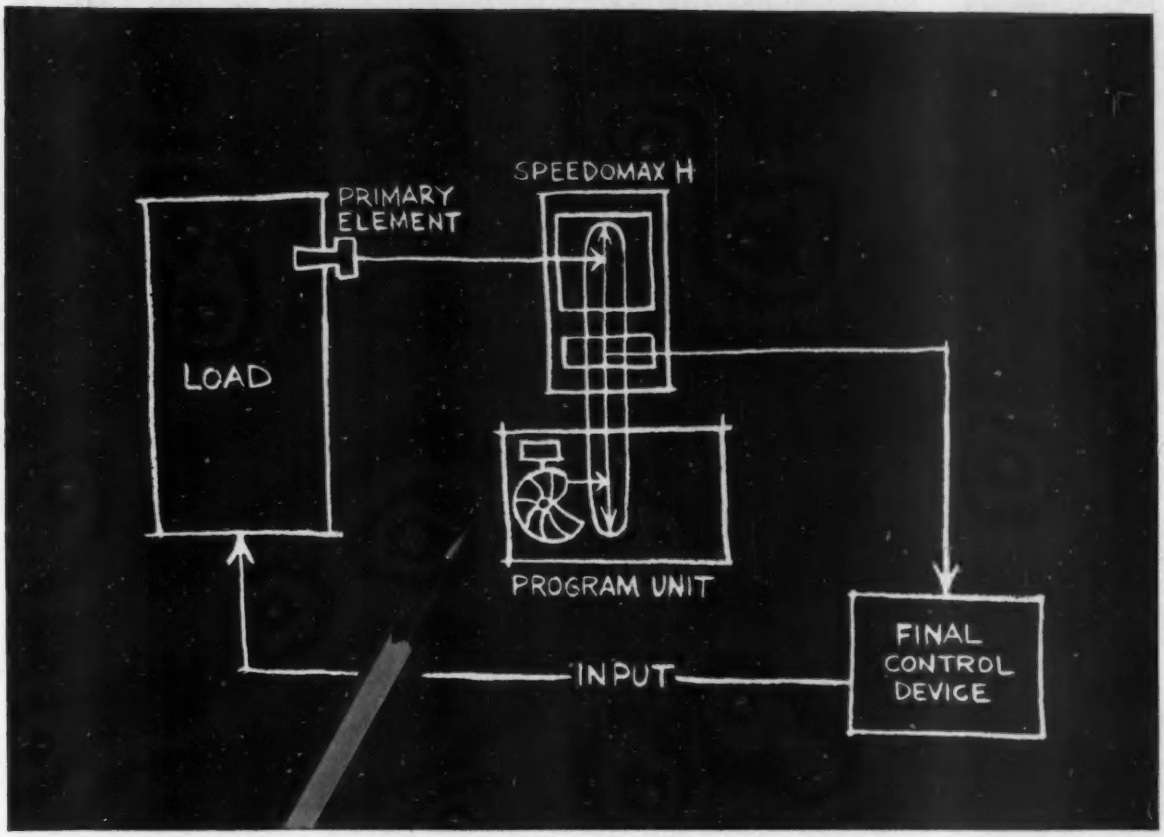


# *Reproduce your time-temperature cycles exactly with L&N cam-type program control*

**At the flip of a switch** you can heat . . . soak . . . and cool at a preset rate for a preset time with L&N's improved cam type program control! Whether your program is linear or non-linear, this control will continuously regulate input to reproduce *your* cycle . . . again and again.

Heart of the system is the program unit. Essentially it's a motor-operated cam and a control slidewire. The cam is calibrated . . . making it extremely easy to lay out and cut to any time-temperature cycle. Changing a cam to meet a new program takes only a minute. For additional flexibility, the unit has seven standard speeds . . . permitting a multiple number of programs.

Other elements in the control system include a primary element, a Speedomax® recorder and associated control relay, and a final control device. Any change detected by the primary element and measured by the recorder is checked by the program unit, which regulates the final control device to keep the process on cycle.

Also available is a motor-operated front setter type of program control. Recommended for linear programs only, this system offers great flexibility within the range selected.

Both types are available for Two-Position or proportioning control . . . will regulate input to electric or fuel-fired furnaces.

*Can your process benefit from programmed heating and cooling? If so, it'll pay you to investigate L&N program control. For more information, call your nearest L&N office, or write 4918 Stenton Ave., Philadelphia 44, Pa. Ask for Data Sheet ND46-33(4).*

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**Other significant advantages include:**

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- Twenty volts BVEBO
- Low noise type available in both PNP and NPN
- Minimum change in characteristics with temperature, current, and voltage
- Suitability for complementary circuits

**For both PNP and NPN Silicon Transistors specify RAYTHEON**

FOR LARGE SIGNAL APPLICATIONS (Temperature Range −65°C to +160°C)

| | Type | $I_{EO}$ or $I_{CO}$ at $V_{CB}$ = 20 $V_{dc}$ μA | $V_{CE}$ max. volts | $h_{FE}$† ave. | $r_b'$ f = 1Mc ohms | $r_c$ kilohms | Noise Figure db (max.) | $c_{ob}$ f = 100Kc ave. μμf | $f_{ab}$ ave. Kc |
|---|---|---|---|---|---|---|---|---|---|
| N | 2N327A | 0.005 | −40 | 15 | 1200 | 500 | 30 | 65 | 200 |
| N | 2N328A | 0.005 | −35 | 30 | 1400 | 500 | 30 | 65 | 300 |
| N | 2N329A | 0.005 | −30 | 60 | 1500 | 500 | 30 | 65 | 400 |
| N | 2N619 | 0.005 | 50 | 15 | 2000 | 500 | 30 | 35 | 200 |
| N | 2N620 | 0.005 | 40 | 30 | 2500 | 500 | 30 | 35 | 350 |
| N | 2N621 | 0.005 | 30 | 60 | 2700 | 500 | 30 | 35 | 500 |

†for PNP, $I_B$ = −0.1mA; $V_{CE}$ = −0.5V; for NPN, $I_B$ = 0.5mA; $V_{CE}$ = 1.5V

FOR SMALL SIGNAL APPLICATIONS (Temperature Range −65°C to +160°C)

| | Type | $I_{EO}$ or $I_{CO}$ at $V_{CB}$ = 20 $V_{dc}$ μA | $V_{CE}$ max. volts | $h_{fe}$* ave. | $h_{ie}$* max. ohms | $h_{oe}$* max. μmhos | Noise* Figure db | $c_{ob}$ f = 100Kc ave. μμf | $f_{ab}$ ave. Kc |
|---|---|---|---|---|---|---|---|---|---|
| N | 2N1034 | 0.005 | −40 | 15 | 3000 | 70 | 30 | 65 | 200 |
| N | 2N1035 | 0.005 | −35 | 30 | 3000 | 85 | 30 | 65 | 300 |
| N | 2N1036 | 0.005 | −30 | 60 | 3000 | 100 | 30 | 65 | 400 |
| N | 2N1037 | 0.005 | −35 | 30 | 3000 | 85 | 15 | 65 | 250 |
| N | 2N1074 | 0.005 | 50 | 15 | 3500 | 70 | 30 | 35 | 200 |
| N | 2N1075 | 0.005 | 40 | 30 | 3500 | 85 | 30 | 35 | 350 |
| N | 2N1076 | 0.005 | 30 | 60 | 3500 | 100 | 30 | 35 | 500 |
| N | 2N1077 | 0.005 | 30 | 25 | 3500 | 85 | 15 | 35 | 300 |

*$V_C$ = 5V; $I_E$ = 2mA

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# Control ENGINEERING

MAY 1959
VOL. 6 NO. 5

**Published for engineers and technical management men who are responsible for the design, application, and test of instrumentation and automatic control systems**



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# Control ENGINEERING

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**NEW CMC DUAL PRESET COUNTER FOR**
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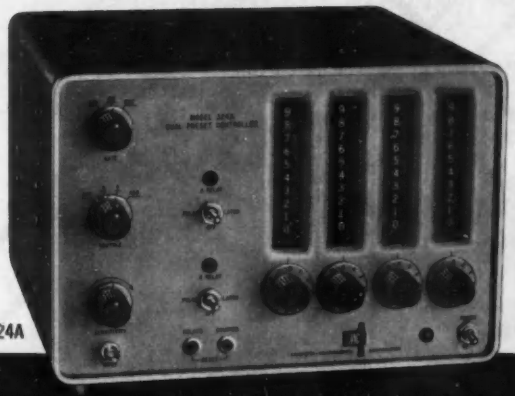


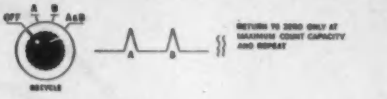
Model 324A

# Only CMC's new Dual Preset Counters have 4 Modes of Operation

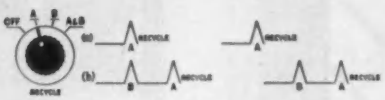
New CMC Dual Preset Counters provide output information at any two pre-selected counts within the capacity of the unit up to 40 kc. Input pulses are obtained from any standard transducer. With an 0.05 v rms input sensitivity, external amplifiers are seldom necessary.
CMC's unique digit circuitry *prevents* miscounting and extends the capacity of the instrument beyond its apparent range — in some applications, a 4 decade CMC instrument offers the same operating performance as other 5 decade types.

**KEY SPECIFICATIONS**
**DECADES** *3, 4, 5 or 6* • **COUNT CAPACITY** *Up to 1,000,000* **INPUT FREQUENCY** *To 40 kc* • **OUTPUT** *Pulse and relay simultaneously* • **OPTIONS** *Rack mount, 400 cps operation, 5 digit mechanical register, 5 mv preamp, digital printer or inline readout output* • **PRICE** *3 decade $615; 4 decade $715; 5 decade $815; 6 decade $915.*

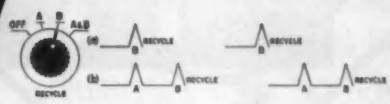
**MODES OF OPERATION**



**1.** With RECYCLE switch in the OFF position, output information is obtained at both the first and second preset selections but the counter continues to totalize, until the maximum count capacity of the instrument is reached. The counter then resets to zero and repeats the cycle as above.



**2.** With RECYCLE switch in the A position, (a) output information is obtained from the A channel and the instrument recycles on A. (b) If the B channel selected number is less than the A channel number, the unit will provide output information at B and continue on to the A channel selection as above.



**3.** With RECYCLE switch in the B position, (a) output information is obtained from the B channel and the instrument recycles on B. (b) If the A channel selected number is less than the B channel number, the unit provides output information at A and continues on to the B channel selection as above.

**4.** With RECYCLE switch in the A & B position, the instrument provides output information and recycles alternately on the A & B channels. For example, when the unit is recycling on A, B is ignored and when recycling on B, A is ignored. This position is ideal for generating a chain of variable spaced pulses.

CMC engineering representatives are located in principal cities. After you've checked the key specifications, give your nearest CMC representative a call. He'll be happy to arrange a demonstration. For complete technical information, please write Dept. **085.**

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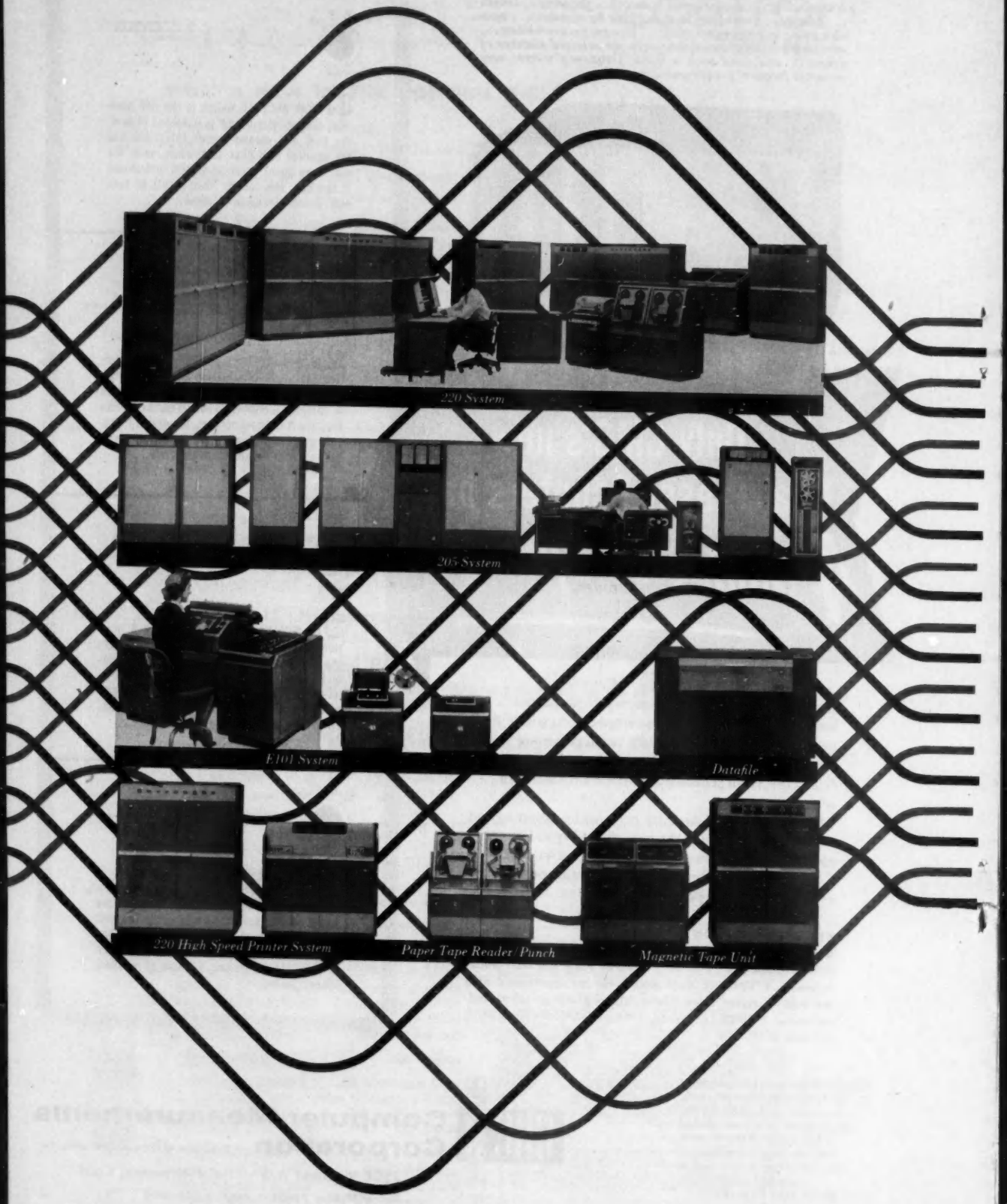
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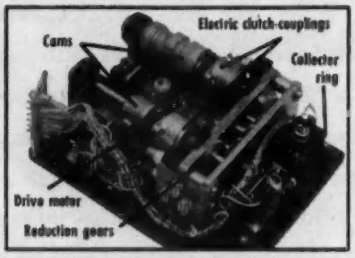
*electric motion control FACTS for IDEA MEN*

## electric clutches actuate missile-firing timer

Here's an idea for an automatic coupling that may help solve some of your motion control problems.

The trick was to design an air-to-air missile-firing timer to fit in the wing of an all-weather interceptor, keeping it lightweight, simple, and maintenance-free. Clutches would have to function at temperatures from −67° F to +275° F—a 342° spread.




The firing sequence timer, powered by a 0.1 oz in. rated, 12,000 rpm motor, uses three separate timing cams driven at different speeds. Warner stationary-field clutches (less than 1" in diameter) provide a simple, compact device for coupling the cams to their input shafts. This lets the motor and input shafts run continuously. Transfer of shaft rotation to the timing cams by electromagnetic engagement of the armature and rotor simplifies the problem of remote control.

Temperature extremes are no problem. Simple design, positive no-slip engagement, and fast heat dissipation avoid the need for special cooling or lubrication. Stationary-field design and low current actuation rule out arcing at cold temperatures or high altitudes.

Simplicity of electric clutches is a major factor in reliability. All wear is on the easy-to-replace rotor and armature. No wear adjustments are necessary. Clutches maintain precise air gaps and clearances, withstanding repeated impacting caused by rotation of the carriage and motion of the plane.

**WANT MORE IDEAS?** Whether your problem is speed control, automatic indexing, fast cycling, or tension control, Warner can furnish factual case histories showing results you can expect from electric brakes and clutches. Write today.

WARNER **ELECTRIC BRAKES AND CLUTCHES**

**Warner Electric Brake & Clutch Co.**
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**CIRCLE 8 ON READER-SERVICE CARD**

# SHOPTALK

### Adjustable-speed drives—ac or dc?

In recent years, the ac motor has been considered mainly a constant-speed prime mover; where high-power adjustable-speed electrical actuators have been necessary in position or speed-control systems, dc motors have been used. But lately there's been a resurgence of interest in the ac motor as an adjustable-speed actuator: conventional induction-motor-control techniques are being reevaluated, and new types of drives investigated. There is no rectification problem with ac drives, and in some cases they are superior to dc.

To bring CtE's readers up to date on the status of ac adjustable-speed drives, the editors asked Purdue's Prof. C. S. Siskind to prepare a special report for the June issue. Future issues will develop this topic by describing new ac drives that are becoming available both here and abroad.

### Perforations are here to stay

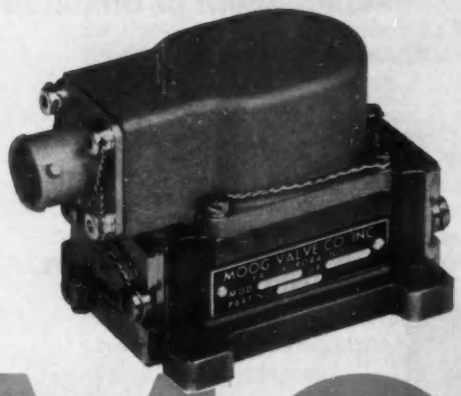
When we started perforating the feature forms some months ago we asked for your vote: do you want us to keep perforating or not? Well, the ballots are still flowing in, but there's no question about the outcome: the vote's for perforations about 10 to 1. So from now on you'll be able to easily tear out those articles that you want to file.

### Three different hats on the same head

The "common denominator" aspect of the control engineering field showed up in an interesting way last month. Assistant Editor Ed Kompass hit the road to cover three different technical meetings, all in one week, and all of importance to CtE readers. (The meetings: International Atomic Exposition and Nuclear Congress; ISA Second National Symposium on Chemical and Petroleum Instruments; and AIME Open Hearth Steel Conference, and Blast Furnace, Coke Ovens & Raw Materials Conference.) The engineers at these meetings all wear different end-process hats, but those concerned with control talk the same language. Watch *What's New* next month for Ed's report.

### International control

Since CtE was conceived, the editors have labored to keep you up to date on the status of automatic control overseas. Scanning this issue, it looks as though we're beginning to succeed. Six major items deal with foreign control advances: *from France*—speed considerations of reactor control rods (page 101); *from England*—control system converts standard lathe to money-making automatic (page 112), "feed-forward" improves feedback controls (page 136), an automatic commutator undercutter (page 149); *from Russia*—controls increase blast-furnace production (page 31), economic justification proves control payoff (page 37).




**series 31 and 32**

# flow control

**servovalves**

*with mechanical feedback*

*from* **MOOG:**

**New performance levels can now be achieved at environmental extremes in advanced aircraft and missile applications. These light, compact, reliable servovalves are available in quantity to your specifications. Consult Moog for precision electrohydraulic servovalves, servoactuators and integrated servosystems.**

*WRITE FOR CATALOG 310*

**MOOG** SERVOCONTROLS, INC. PRONER AIRPORT, EAST AURORA, N. Y.

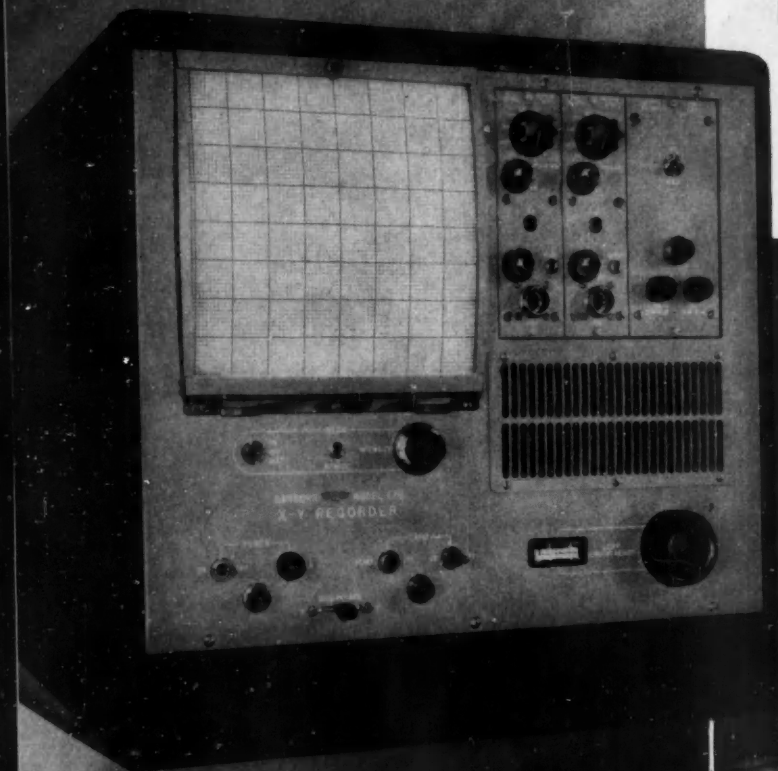
LEADING INNOVATOR AND PRODUCER OF ADVANCED ELECTROHYDRAULIC SERVOVALVES

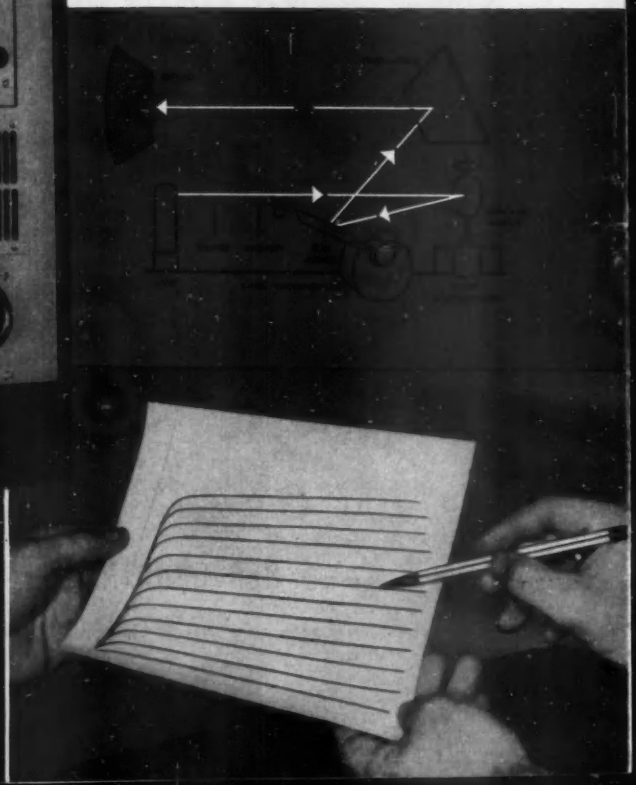
# 100 CPS X-Y RECORDING

## with immediate readout

**THE NEW SANBORN MODEL 670 OPTICAL X-Y RECORDER HAS**

- ★ 1% linearity
- ★ frequency response 3 db down at 130 cps independent of amplitude
- ★ writing speeds to 2500 in/sec.
- ★ 8" x 8" direct print paper chart
- ★ trace monitoring on phosphorescent screen

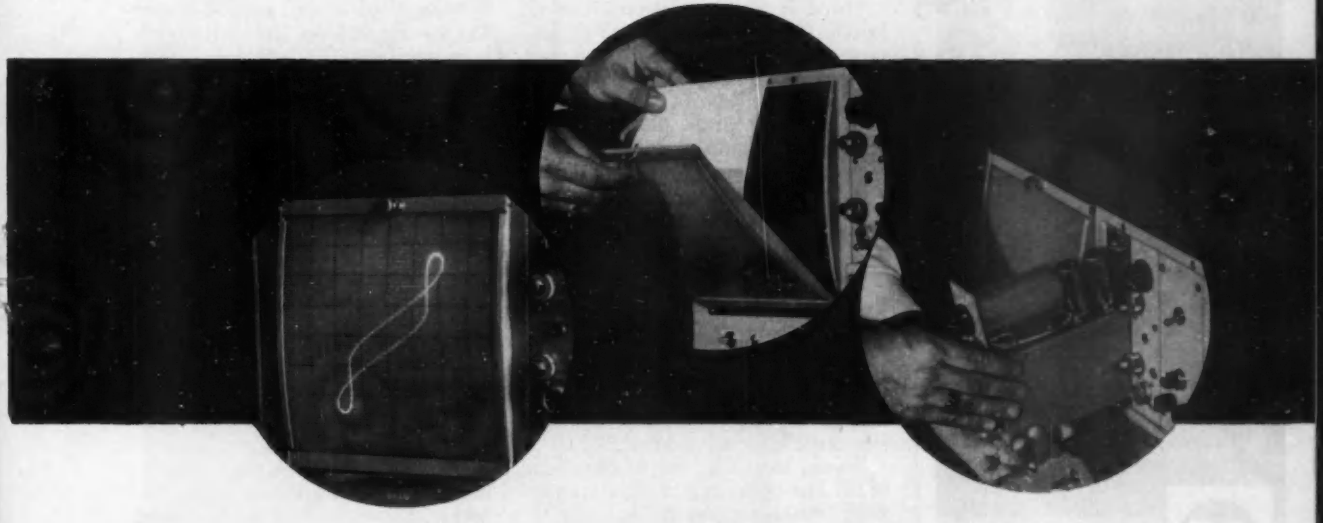


**X-Y** RECORDING never before possible with electromechanical instruments can now be done with the new Sanborn Model 670 X-Y Recorder. Direct writing on ultraviolet-sensitive recording paper by a beam deflected by optical galvanometers makes possible the combination of fast writing speed and 130 cps frequency response not found in any other X-Y recorder. Transistor characteristics, acceleration and vibration of mechanical parts and events of similar short duration can be recorded with linearity of *1% of full-scale* and at trace speeds as fast as *2500 inches per second*. Square wave response exhibits no greater than ½% overshoot *at any amplitude;* sensitivities as high as 62.5 uv/inch (depending on preamplifier used).

PLOTS OCCUPY AN 8″ x 8″ RECORDING AREA and can be previewed or monitored on the instrument's phosphorescent screen. An Axis Record switch to print X and Y axes on the record, and a Beam Intensity Control to assure maximum trace clarity, are among the front panel controls provided. An 8″ x 8″ sheet of the ultraviolet-sensitive chart paper (stored in drawer at base of cabinet) is easily placed on the back of the hinged screen. Brief post exposure in normal room light is the only developing process.

OPTIONAL INTERCHANGEABLE PREAMPLIFIERS for each axis presently include the Model 850-1300B DC Coupling and Model 850-1200 Phase Sensitive Demodulator; a Carrier Preamplifier, High Gain Preamplifier and a time base generator are now in development. Driver Amplifiers are compact, fully transistorized plug-in units with single-ended input and output. Galvanometers are low resistance, low voltage units of rugged, enclosed construction; sensitivity and damping are independent of coil temperature. Accessible, unitized circuitry also extends to the power supplies—a front-panel plug-in for both preamplifiers and a second supply for both driver amplifiers. A built-in blower provides constant, forced filtered air cooling. The Recorder can be rack mounted in 15¾″ of panel space, or housed in its own 20″ x 20″ x 21¼″ optional portable cabinet.



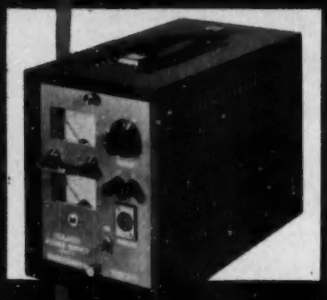
Ask your local Sanborn Sales-Engineering Representative for complete information on the Model 670 X-Y Recorder, or write the Industrial Division in Waltham, Mass.

# SANBORN COMPANY

INDUSTRIAL DIVISION • 175 Wyman Street, Waltham 54, Massachusetts

CIRCLE 10 ON READER-SERVICE CARD

Absolute
ISOLATED DC POWER SOURCE



for

- RESISTANCE-TYPE TRANSDUCERS
- STRAIN GAGES
- ACCELEROMETERS

Now for the first time you can have the dependability and ease of operation of an electronic power supply *plus* the isolation normally obtained only from a battery. The Moeller Model 21 Power Supply exclusively provides *absolute isolation from line voltage and line ground.*

The Model 21 provides 0-20 volts, 1 amp of power for strain gages and resistance-type transducers. This transistorized instrument gives improved performance with existing single-ended and differential amplifiers and offers voltage regulation, internal impedance, ripple and stability equal to, or superior to, conventional transducer power supplies.

*Write for descriptive literature.*

MOELLER
INSTRUMENT CO.
ELECTRONICS DIVISION
132nd Street & 89th Avenue
Richmond Hill 18, N. Y.

CIRCLE 11 ON READER-SERVICE CARD

# FEEDBACK

## PROBLEM FORUM

**Here's a challenging instrumentation problem. A cam manufacturer requires measurement and recording of plate-cam contour to extreme accuracy over a wide range. If you can offer a practical solution, send it in. Your solution will earn you dollars if published.**

TO THE EDITOR—

We would appreciate your help in locating an instrument system that will handle these requirements:

1. Measurements must be in inches with an accuracy to 0.0001.
2. Range of measurement, 0 to 3 in. or more. (At present we use a 1-in. travel dial indicator and reset with rods.)
3. The measuring instrument selected should also be able to transmit a signal to a recording printer to print out dimensions taken.
4. The purpose of this instrument is to print out radial dimensions on cam profiles as they are indexed every 30 minutes of a degree.

*Howard H. Evans*
*Commercial Cam & Machine Co.*
*Chicago, Ill.*

**Theodore Kaslow, vice-president of Decker Corp., Philadelphia, Pa., has suggested a null-balance system incorporating a narrow-range position transducer carried on a servo-driven precision screw thread, plus a counter-type indicator and a recording printer. What other suggestions are there? Can you be more specific? Ed.**

### Are proximity switches satisfactory?

TO THE EDITOR—

Your [January] editorial, "What the Editors See for '59", made very interesting reading. Of particular interest to me were your predictions for static controls and your statement that development work is necessary to produce a satisfactory proximity switch (for static controls—Ed.).

To our knowledge, Electro was one of the first companies to pioneer proximity switches, with its first efforts introduced in 1952 and 1953. Since that time, a few others, such as Minneapolis-Honeywell, Square D, and Westinghouse, have introduced somewhat similar products. To-date we feel that the principle behind the Electro Proximity Switch puts the switch considerably ahead of anything on the market. Its features are these:

- Detects both ferrous and non-ferrous metals. Is sensitive to very thin metal pieces, such as aluminum foil. Does not attract or hold ferrous chips.
- Metal pieces as small as 0.1 in. and as large as an automobile can be detected, by selection of the proper coil size for the detector system. Our smallest probe has a $\frac{1}{8}$-in. diameter and can be provided with an overall length of $1\frac{1}{4}$ in. Larger sizes up to 12 in. can and have been manufactured for our customers.
- Pickup probes are relatively inexpensive, the list price for our least expensive probes being $13.50 each. (Plus $100 to $135 for the electronic package.—Ed.)
- Pickups are extremely rugged and can be provided for operation where there is water, oil, and dirt.
- Proven reliability. Although standard tubes and relays are used in the control circuit, our equipment has been proven to be reliable by such groups as the Plymouth Engine Div. of Chrysler Corp. at its Mound Road plant in Detroit. This group has had one Electro Proximity System in operation for the past three and a half years on shifts running as long as 18 hours per day. No maintenance to-date has been required on this equipment, not even to the extent of changing tubes.
- Another one of our very good customers is Cincinnati Milling Machine, which has been purchasing our equipment for approximately two years, for the sensing of parts in its Microcentric grinding machines. Here again, reliability has been proven.

It is true that we have not transistorized our circuits, nor mag-amped the output, but is this necessary for most industrial applications? With our present control circuits using vacuum tubes, it is easy for us to provide what we call "delayed-make, fast-break" or "quick-make, slow-break" output action with the passage of parts in front of our pickups. Zero-speed indication is also relatively simple for us to in-

**NO OIL – NO AIR . . .** NORWOOD CONTROLS

**VALVE POSITIONER IS**

# ALL ELECTRIC

EXPLOSION-PROOF
HAND WHEEL
STANDBY ELECTRIC POWER LOW AS 50 WATTS
PREDETERMINED THRUST LIMIT
MECHANICAL BRAKE
MOTOR RUNS ONLY WHEN STEM MOVES
HIGH POWER OUTPUT
MAXIMUM THRUST 1000 LBS.
• ADAPTS TO SIGNAL FROM ANY AVAILABLE ELECTRIC CONTROLLER
• MERCURY WETTED POWER RELAYS—VIRTUALLY INFINITE LIFE
• ADJUSTABLE STROKES ½" TO 2"
NORWOOD
MASONEILAN

Norwood Controls Valve Positioner mounted on 4-inch double-seated valve.

Maintenance problems drop almost to zero when you install Norwood Controls' new all-electric Valve Positioner. No air or hydraulic leaks, no cleaning, no expensive auxiliary equipment . . . just one, efficient, pre-lubricated, all-electric unit that operates from −40°F to 170°F.

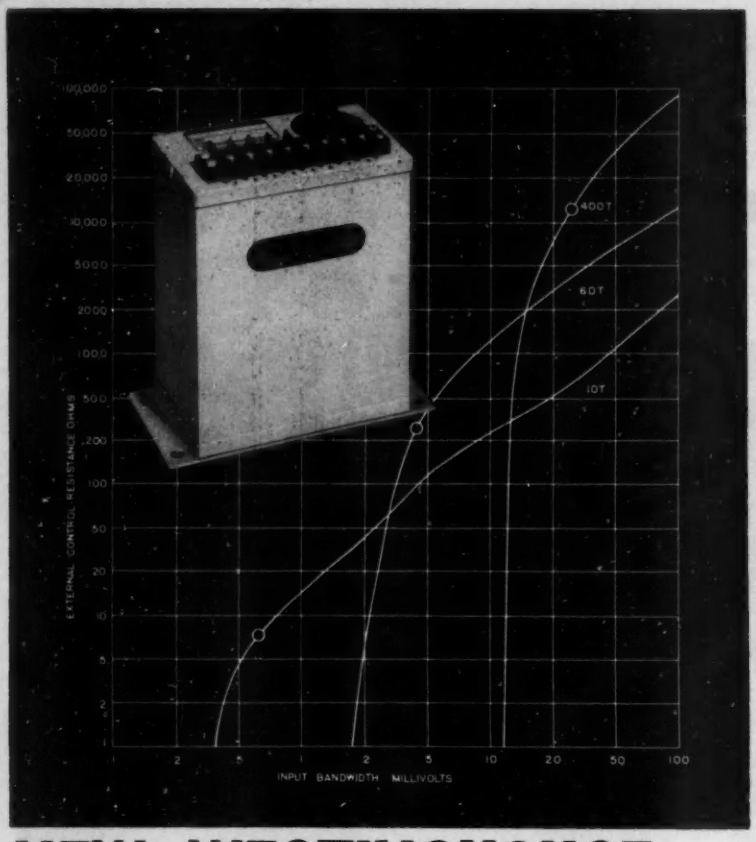
For further information, write for data sheet B158-5. Norwood Controls Unit, Detroit Controls Division, 938 Washington Street, Norwood, Mass.

American-Standard PRODUCTS

**AMERICAN-Standard**

DETROIT CONTROLS DIVISION

CIRCLE 12 ON READER-SERVICE CARD




# NEW WESTINGHOUSE BISTABLE AMPLIFIER

## Ultra-Sensitive On-Off Static Amplifier

BISTABLE AMPLIFIER combines magnetic and transistor circuitry for an input sensitivity of 5 x $10^{-8}$ watts a-c or d-c. The output power is 6 watts at 24 volts d-c. This output is sufficient to drive auxiliary relays or static power amplifiers.

For current-control problems or voltage regulation, check these Bistable features:

- No tubes . . . no moving parts . . . no maintenance
- Exceptional sensitivity, 5 x $10^{-8}$ watts
- Multiple control windings
- A-C or d-c input signals
- Fast response . . . 20 milliseconds
- Economical . . . less expensive than relays
- Military versions available

GET ALL THE FACTS: Write Westinghouse Electric Corporation, Director Systems Department, 356 Collins Avenue, Pittsburgh 6, Pennsylvania. Complete information on the new Westinghouse Bistable will be sent to you by return mail. J-01009

YOU CAN BE SURE...IF IT'S Westinghouse

WATCH "WESTINGHOUSE LUCILLE BALL-DESI ARNAZ SHOWS" CBS TV MONDAYS

CIRCLE 13 ON READER-SERVICE CARD

## FEEDBACK

corporate in our present control circuits. Please refer to our Proximity Information Bulletins 1, 2 and 4B, describing such circuits. To transistorize such modified circuits to meet particular customer requirements would be difficult. Our control circuit is also versatile in that we can provide either relay-type output or 5-volt dc pulse output to operate other control circuits.

• We do have plans to provide our control unit (the electronic package) as a plug-in, solid-state, static-switching type package.

*R. C. Crossley*
*Electro Products Laboratories, Inc.*
*Chicago, Ill.*

**A technical controversy over new classes of products presents a golden opportunity for clarifying merits. To help find the answers in this particular controversy, we interviewed control engineers in industry who have used, or are planning to use, proximity switches. Before the fourth quarter of this year, we will publish an evaluation of proximity switches, prepared by the manager of development of a machine tool manufacturing company. Our comments in this column represent the combined findings of our interviews.**

**The core of the controversy is the word "satisfactory". Proximity switches do, according to those interviewed, a creditable job where absolute fail-safe is not required and where failure will not cause a wreck. They have not reached the point of general use in place of electromechanical limit switches. To be satisfactory, they should meet most of the following requirements:**

**• Cost no more than a standard limit switch (someday, maybe—Ed.)**

**• Occupy no more room (including the amplifier) than a standard limit switch (is this absolutely necessary?—Ed.)**

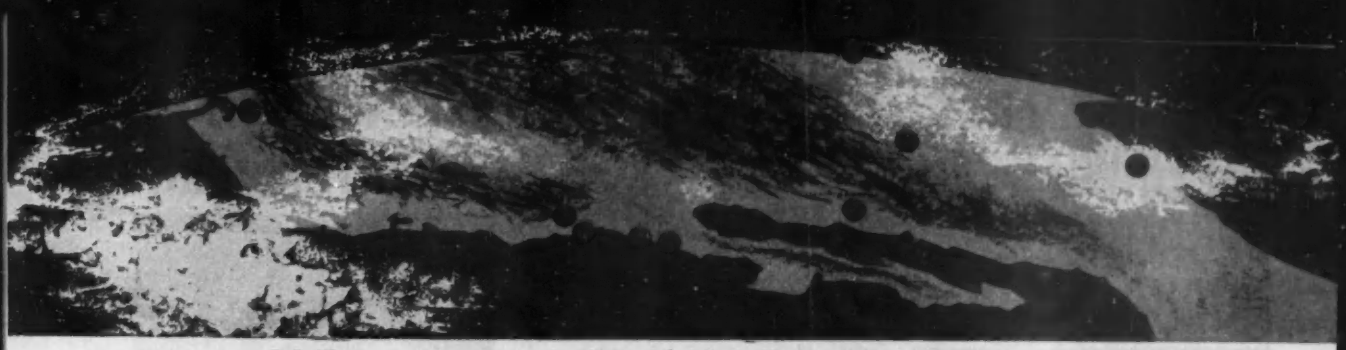
**• Have the "snap action" that a standard limit switch has and not be actuated by noise from transformers, soldering irons, etc. (realistic and technically possible—Ed.)**

**• Have output capacity for handling conventional relays (realistic in some cases—Ed.)**

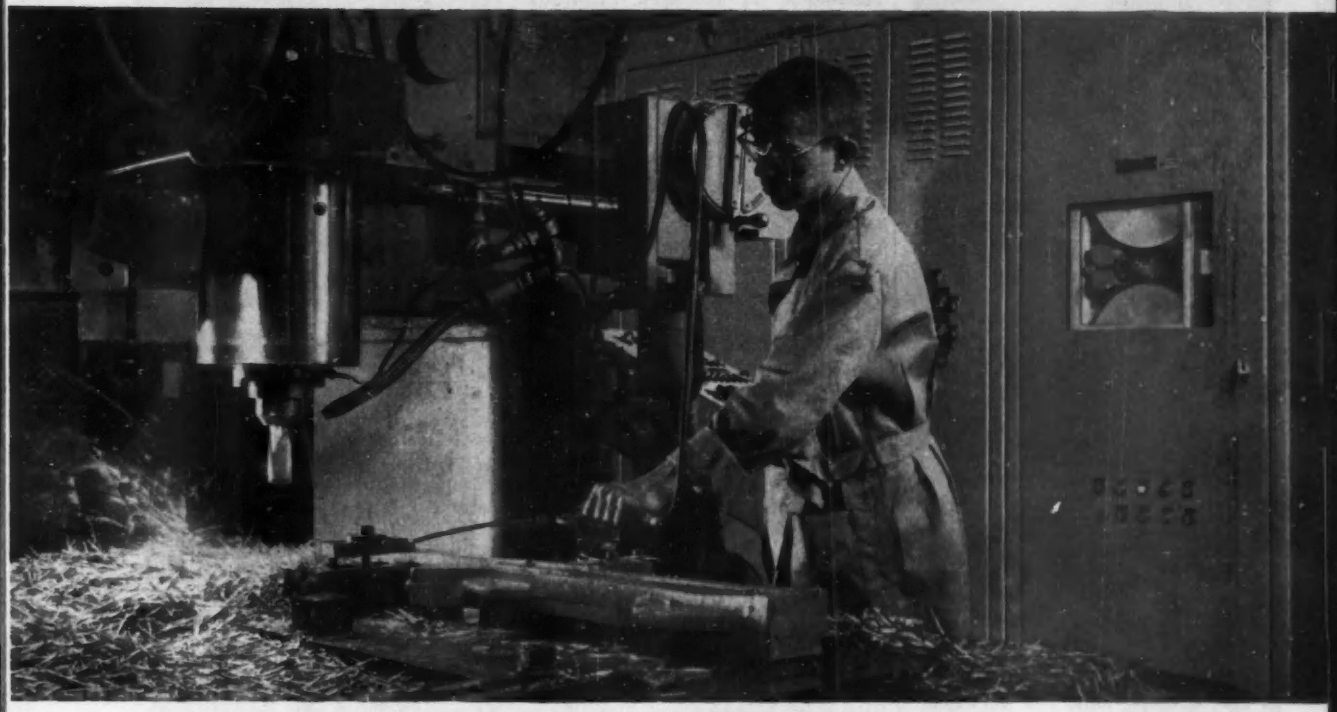
**• Where necessary, have accuracy of precision limit switch or Microswitch (realistic—Ed.)**

**• Be fool-proof (what's that?—Ed.)**

**Too much has been made of limit-switch troubles that result from improper applications. Properly applied, a standard limit switch is hard to beat for reliability. At the same time, isn't**



# Where the shape of things to come



# is programmed by AMPEX tape recorders

The profiler above is shaping parts for new Lockheed Electras. Exact tool positions are being defined by command signals—as many as 200 per second—from the Ampex FR-100 in the control system to the right of the machine.

The accuracy of such a milling operation increases with the number of points defined per inch of tool motion. One reel of magnetic tape defines millions of points, programming up to 1½ hours of continuous machine operation. Recycling a tape loop will program an entire run of identical work-pieces.

Shaping parts by command signals from Ampex-equipped automatic control systems is now routine production operation at such places as Lockheed in Burbank, Martin at Denver, Rohr at Chula Vista, Convair at Ft. Worth and San Diego, and Giddings & Lewis at Fond Du Lac, to mention only a few.

Even though punched cards and paper tape are still proving adequate for many of today's less-sophisticated automatic control installations, systems engineers are increasingly interested in the superior speed and data-handling advantages of magnetic tape. An Ampex FR-300, for instance, can extract a short burst of digital information equal to that on an entire punched card in less than 4 milliseconds, including start and stop.

In configurations like the one illustrated, the advanced Ampex FR-100A, with its 14 tracks on 1-inch tape, has ample reserve for extra functions. Six tracks may be used for tool-position coordinates; others for start, stop, coolant, or even voice instructions.

Whether you believe the future of automatic control lies in point-to-point positioning, continuous-path control, or both—Ampex magnetic tape recorders have built-in reserve capabilities which make them worthy of consideration as a component for any control system designed for tomorrow's needs.

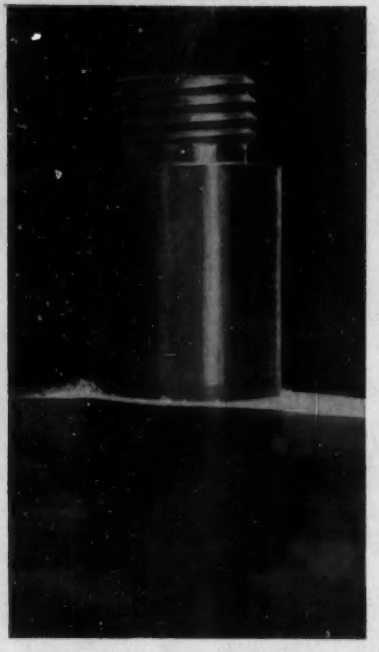
*First in magnetic tape instrumentation*

AMPEX
CORPORATION

AMPEX INSTRUMENTATION DIVISION
934 Charter Street, Redwood City, California
Offices in USA and Canada. Engineering representatives cover the world.

CIRCLE 14 ON READER-SERVICE CARD

# MEASURE FUEL LEVEL WITH MICROMETER ACCURACY!



ACOUSTICA ULTRASONIC continuous gauges and liquid level switches are unequaled for the measurement and control of LOX, kerosene, nitric acid and exotic fuel. Accurate up to 1/64 inch... unaffected by liquid variables... operate instantaneously... consume infinitesimal power... no spark or radiation hazard. Now integrated in major military propellant utilization and liquid control systems. Expert Acoustica engineers can help you with your gauging problems. Send for further information.

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CIRCLE 15 ON READER-SERVICE CARD


## FEEDBACK

**it possible that the tube has been made the whipping boy in proximity switching systems? Tube-failure dangers have been met in some electronic control devices by requiring operation of a relay, by the tubes, before a critical step in a sequence of programmed operations can occur; and by dropping out a relay to indicate completion of the step. Unfortunately this provision makes this system a little more expensive.**

**Applied to the Cincinnati Milling Microcentric grinder, the proximity switch is operating in a "permissive" manner. If it fails, the next step does not take place. The program control is therefore "fail-safe".**

**Mr. Crossley forwarded this description of the Electro Products permissive system, soon to be available. Ed.**

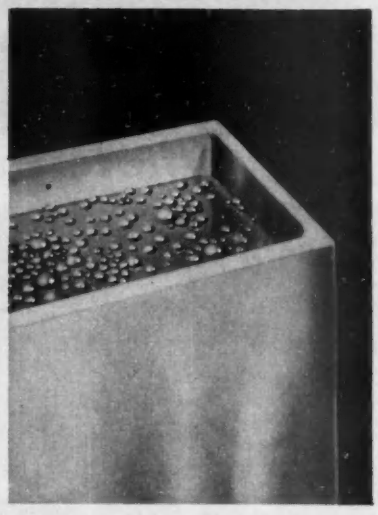
To the Editor—

Our tentative catalog sheet 52.043 and price list describe our Positive Action Proximity Control. The schematic wiring diagram in the sheet shows the pickup coil connected in series with the cathode tap of a control-circuit tank coil. With no metal present at the pickup probe, the coil in the pickup, together with the cable capacity and an internal capacitor, resonate at a frequency which is the same as that of the main oscillator section. When metal comes into the field of the coil, the frequency is shifted, reducing the impedance, allowing more feedback to the main oscillator section, and inducing oscillation. All circuit components must be functioning normally before the control relay can be energized. There is one point in the circuit where a false signal could occur, and this would be in the final tube bias supply. A solid-state rectifier supplies dc voltage from a separate secondary on the transformer to maintain the final tube biased to cutoff. Since there is a very low current drain on this rectifier, the chances of this circuit's failing are quite remote.

This equipment is now on test in the Washington, D. C., Post Office. Its application is in the Mail Flo system [see page 22—Ed.] wherein the pickups sense coded information (copper strips) placed on the side of plastic trays for identifying and controlling the flow of these mail trays. Our last contacts from Industrial Nucleonics Corp., which has the subcontract on control systems at the Post Office, indicate 100 percent accuracy from our equipment.

*R. C. Crossley*


# ULTRASONIC BREAKTHROUGH!



# ONLY ACOUSTICA ULTRASONIC CLEANERS HAVE MULTIPOWER!

**The Multipower transducer** developed by Acoustica research, multiplies the power and efficiency of ultrasonic action. Cleaning is faster, better, labor costs are lower. Acoustica ultrasonic cleaners are built for performance and durability. They are engineered to the finest standards, unequaled in quality and value.

Off-the-shelf in capacities from 1 to 75 gal. or custom built to 5000 gal. and more. Expert Acoustica engineers can help you with your cleaning problems. Send for further information.

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Send information describing advantages of Acoustica ultrasonic cleaners.
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CIRCLE 16 ON READER-SERVICE CARD

# PNEUMATIC transmitting tachometer with DIRECT LINEAR SIGNAL

## the Foxboro Type 16A Pneumatic Speed Transmitter

Here's a tachometer with 3-15 psi air signal *directly proportional* to rpm! Speed changes are recorded on a uniform-scale chart. Accurate measurements of rpm are easy to read throughout the entire range. No crowded bottom scale!

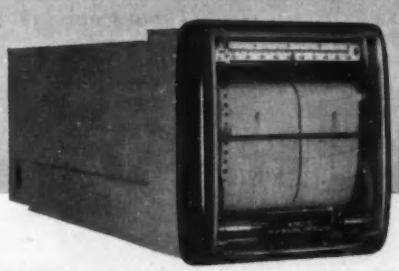
The Type 16A Speed Transmitter is available for ranges from 0-600 rpm to 0-6500 rpm. Full-scale accuracy of ±½% is consistently maintained. Small and light weight, it can be mounted *in any position* — never needs lubrication.

For rotating equipment having wide speed variations, the Type 16A is ideal. It's available for either clockwise or counter-clockwise rotation, and can easily be incorporated into any present pneumatic control system. Write for full details. **The Foxboro Company, 365 Norfolk Street, Foxboro, Massachusetts, U.S.A.**

- **Mounts in ANY position**
- **Accurate to ±½% across entire range**
- **Needs no lubrication**
- **Dust-tight gasketed case continuously purged**
- **Simple force-balance mechanical principle.**

*Direct-connects to remote pneumatic recorder or controller, such as Consotrol® panel recorder shown below.*

*®Reg. U.S. Pat. Off.*

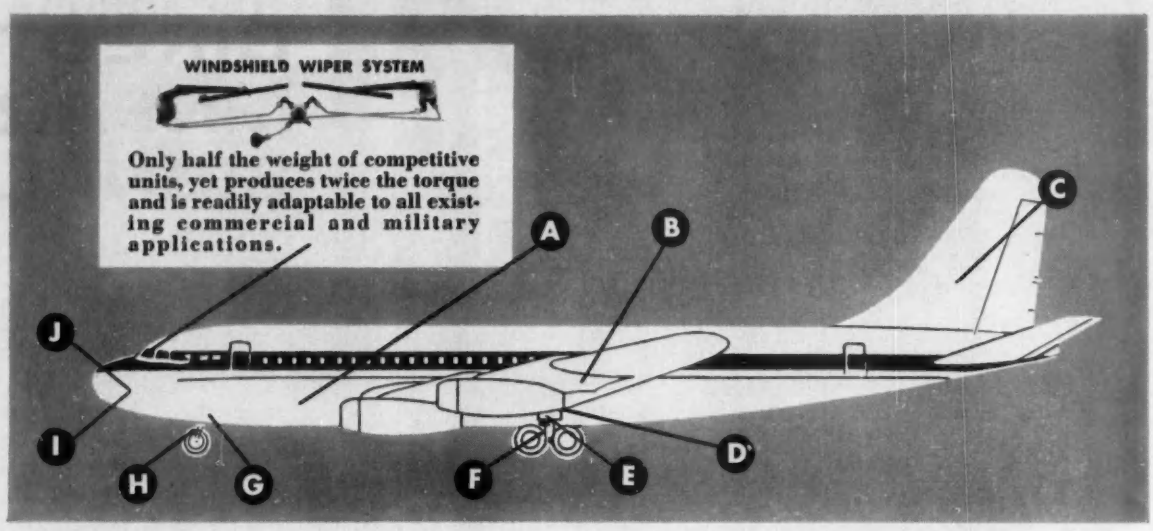


FOXBORO
REG. U. S. PAT. OFF.

**PNEUMATIC SPEED TRANSMITTERS**

FROM HYDRA-POWER

# Components of Advanced Design for every hydraulic function!




**A SYSTEM MANIFOLD UNIT**

Packages metallic filter, contamination indicator, 4-way, 3-pos. solenoid valve, relief valve, pressure reducer and multiple port connections to save weight and installation costs.

**B 4-WAY, 3 POS. SOLENOID SELECTOR**

Uses stainless steel forged body as the sleeve. This design eliminates more than half the number of packings usually required. Each position is pressure-actuated thereby eliminating dependence on springs.

**C TANDEM SERVO ACTUATOR.**

One-piece tandem construction of the spool and sleeve in the servo valve, machined to reproduce identical flow characteristics, insures optimum output requirements. These servo valves, with low plunger forces, have true linear flow obtained by rectangular orifices.

**D 6 WAY, 4 POSITION SELECTOR**

Combines the functions of two separate valves and controls the landing gear and landing gear doors, using only two solenoids.

**E COMPOUND BRAKE ADJUSTER**

Maintains an established clearance regardless of brake lining wear. It features a compound principle which compensates for master brake cylinders having limited displacement.

**F BRAKE EMERGENCY VALVE**

Meters fluid to each half of dual brakes and insures against complete brake system failure. Unit is a modification of our "AN" approved shuttle valves.

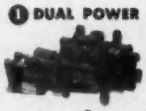
**G DUAL PARKING BRAKE VALVE**

Utilizes a "Belleville" washer cartridge to minimize size. Parking pin lock is stationary during normal operation and does not "steal" brake displacement. "Park" release is positive.

**H STEER—DAMP UNIT**

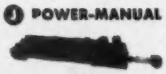
This advanced design has exceptional steering accuracy and shimmy dampening characteristics. It also has the highest torque output versus weight ratio available.

**I DUAL POWER BRAKE**



Unit contains normal and emergency brake valves and incorporates a transfer valve that senses loss of normal pressure and transitions to the emergency system. For use in a 4000 psi, 275° system.

**J POWER-MANUAL BRAKE VALVE**



A power brake valve when pressure is on which transitions to a master cylinder if system pressure is lost, thus eliminating the need for an emergency brake system.

***HYDRA-POWER** welcomes inquiries covering any* **hydraulic** ***requirement — and if it's* electronic, *please contact our subsidiary "Power-tronic Systems, Inc.", same address.***

**HYDRA-POWER CORPORATION**

PINE COURT, NEW ROCHELLE, N. Y.

# Edward E. Kirkham

## . . . . . crusades for logic

If Ed Kirkham has his way, the undergraduate engineer is destined for a liberal dose of logic. "Not just courses such as Boolean algebra, which are based on applied logic and which have become obviously necessary today," says Ed. "I'd like the engineering student to be exposed a little at least to pure logic as the liberal arts major defines it: 'the science of the formal principles of reasoning'."

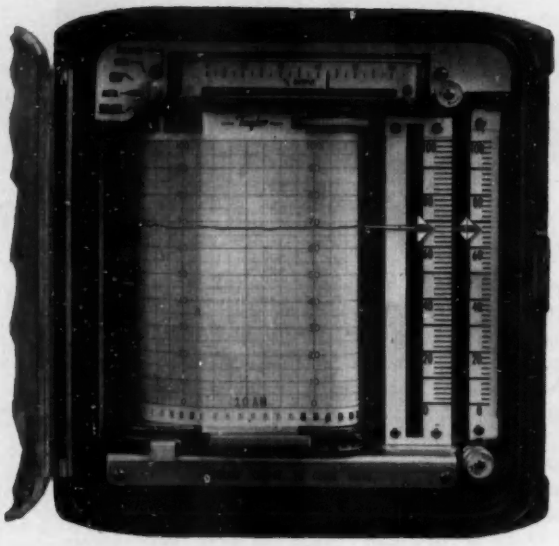
Kirkham's motives are at least partially selfish. As chief development engineer of Pratt & Whitney Machinery Div., he has responsibility for a number of complex machine-plus-controls systems that make extensive use of logical circuitry. The latest version of the P&W numerically controlled jig-borer, for example, features telephone-dial as well as tape input. The dial input offers truly marvelous convenience to the operator, but is accomplished only by the addition of an extensive network of relay switching circuits. So, applied logic has become a routine tool for P&W engineers. Says Ed: "Most design errors can be traced to errors in logic; their numbers probably could be reduced considerably if better reasoning were used. Thus, more highly developed reasoning powers are just as essential to the engineer as they are to the lawyer or other professional."

Kirkham's educational background and professional experience appear to be meticulously planned to suit his present position. For a job of this scope, a personnel director might well write a specification calling for extensive mechanical as well as electrical capabilities. How does a man develop such a combination? In Ed's case, Phase I began with a mechanical engineering degree from Kansas State College in 1942. For the next four years, he put theory to practice in his role of engine designer with the Pratt & Whitney Aircraft Co. In 1946, Kirkham joined Federal Electric Products Co. to participate in the design of magnetic relays and contactors. These devices involve engineering problems that are principally mechanical in nature, but their function is electrical; so Federal provided a good climate for the start of Phase II of Ed's development as a control engineer. In 1953 he came to Pratt & Whitney Machinery Div. (no connection with P&W Aircraft) and plunged into the complex problems associated with tracer and numerical control systems. And in 1954 made all his electrical knowledge "legal" by means of an MSEE degree from the University of Connecticut. He is a registered professional engineer.

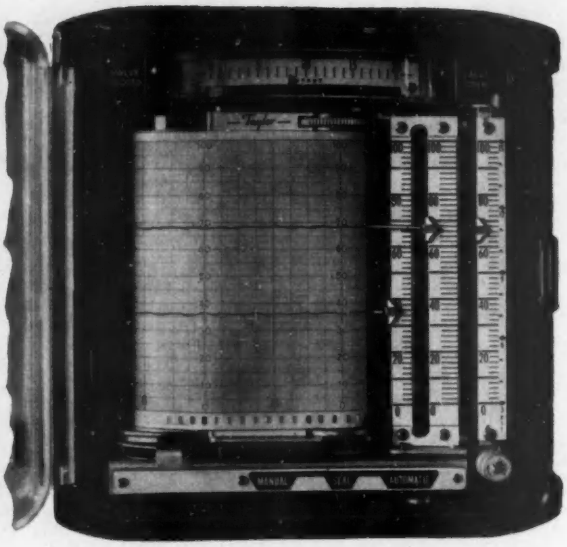
Originally a midwesterner (from Columbus, Neb.), Kirkham has lived in the Hartford, Conn., area since graduation from college. New England "hams" hear from Ed (call letters W1SVK) whenever he has a break in his busy schedule, which includes project assignments from wife Arline and sons Donald and Gary. Society activities, too, claim a good share of Ed's spare time; he was 1958 chairman of the very active National Machine-Tool Subcommittee of AIEE. He is a member also of the American Society for Quality Control.

Recently Kirkham's dynamic boss, Jake Jaeger, moved up to the post of executive vice president. With Jaeger (one of the original MIT control engineers) busy applying the principles of feedback control on a corporate management level, Kirkham now heads mechanical and electrical design as well as development. Despite the stepped-up pace of everyday business, he manages to continue research on one pet blue-sky project, axis transformation. Kirkham's objective: to write general equations relating tool axis to workpiece axis. His interest in this project stems from an interest in missile guidance, where the positions of vehicle axes must be continuously related to those of the reference body (like the earth). Kirkham sees nothing strange in looking for ideas outside the machine tool industry; he believes that control engineers in all industries have much to learn from one another. "After all," he says, "our business is guiding a cutting tool in space; perhaps the missilemen can help us a lot."

# All Process Engineers: Compare Features of the New Taylor Electronic AC or DC Recorder and the exceptional TRANSCOPE* Pneumatic Recorder (90-J)



*701J AC or DC Electronic Recorder*



*90J Transcope Pneumatic Recorder*

**NEVER BEFORE SO MANY FEATURES IN SO LITTLE PANEL SPACE**

**1. Unconfused Readability.** Because chart record, pen and set-point are side-by-side, whether electronic or pneumatic. Target-type pens and pointers are easiest of all to see, even at a distance. The 4″ chart reads from left to right—like a newspaper—on rectilinear coordinates. Thus, operators are encouraged to make frequent readings . . . and they make fewer mistakes because all pertinent data is lined up.

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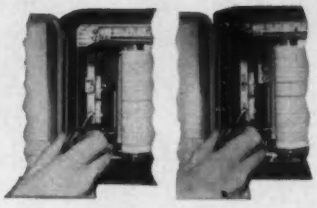
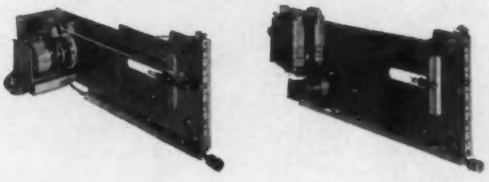
LOOK TO TAYLOR FOR

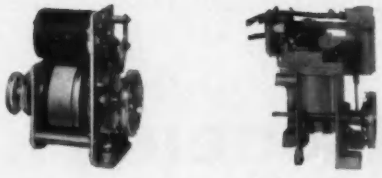
*Taylor Instruments*



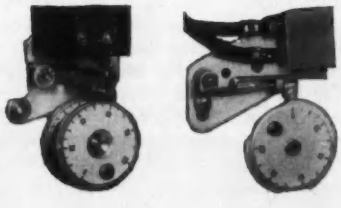
**2. Front Adjustments—a Taylor 'first'.** Controller response adjustments are quickly and easily made from the front, where results can be watched, on both Electronic (left) and Pneumatic (right) instruments. You can visualize immediately all pertinent process information—record, pen and set point



**3. Plug-in Set Point Transmitters,** parallel to and exactly matching chart range, permit comparison without confusion and accurate adjustment of the control point. Separate set point transmitter enables you to stay on fully automatic control, even when recorder slide is removed.



**4. Powerful Servo Motors** give more precise pen positioning than ever before. More accurate records. Unmatched threshold sensitivity. Unparalleled power permits use of process alarms, new inking system and elimination of flimsy linkage.



**5. Built-in Process Protection.** Integral heavy duty alarms can be standard or hermetically sealed for Class I, Group D, Div. 2. Each cam may be set for high or low level or high-low. Contacts can be normally open or normally closed. "Memory Pointers" indicate *magnitude* beyond the alarm setting of the process variable. Cost is substantially less than conventional systems.

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# MEAN ACCURACY FIRST

*Mail-Flo installation at Grand Central Post Office. Primary sorting—into 49 major geographical areas—takes place to right of the aisle; secondary sorting into 70 different classifications takes place at left side. In this installation there are two primary lines, each with seven control consoles (two rows of sorting desks are associated with each console), 15 in secondary sorting; 15 control consoles direct mail down the 30 sorting rows.*

# Post Office Turns Modern

***Big things are happening at post offices throughout the United States as the department's first modernization program picks up speed. Automatic handling, culling, sorting, and reading machines are being developed or installed.***

WASHINGTON—

First real modernization program in the history of the United States Post Office is moving into high gear. After six years of experiment and study, automatic equipment is proving itself, and so is being scheduled for large-scale installation throughout the U.S. With automatic controls, the Post Office is coping successfully with a mushrooming mountain of mail.

Probably the pioneering step was the installation of a prototype system of Mail-Flo—a mechanized method of moving mail during sorting—at Detroit two years ago. Then a full-scale, high-capacity installation was made at New York City's Grand Central Post Office (see photo above). Last month, after a year of tortuous testing, the Grand Central installation had satisfied even the most dubious employees.

Within the next two years, 11 post offices in major cities will be completely made over into modern, semi-automatic plants. Another 15 will get extensive mechanization. Before the program is completed, 1,200 in the U.S. will have Mail-Flo installations.

• **Mail factories**—In the post office with the new look, machines will take incoming mail, separate letters from newspapers and packages, stack them with addresses right-side up, automatically sort them out to hundreds of destinations, and speed them off.

To finance this, the Post Office has requested $50 million in 1960 to procure already developed conveyor systems (like Mail-Flo), culling machines and automatic sorters for the post offices under construction. And the department has asked for $15 million over fiscal 1960 to research and develop additional equipment—a sharp rise from the $6 million this year.

• **Mail-Flo**—Looking at Post Office mechanization, you have to start with Mail-Flo. Basically, it is a system of conveyors that moves mail through stages of sorting. This year, $20 million was spent on Mail-Flo alone (some installations: Grand Central P. O. in New York; Ogden, Utah; Los Angeles; Washington, D. C.). And a good share of next year's $50 million will be spent on it, too. Chief suppliers of this equipment have been Mechanical Handling Systems, Inc., Jervis B. Webb Co., Rapid Standard, and the Butz Corp. Small Detroit control maker, Condeco (Control Design & Fabricators), has supplied a lot of the electropneumatic control.

When the mail arrives at a post

**1** *Mail arrives at terminal post office in trucks, is manhandled onto conveyors.*

**2** *Culling takes place on mezzanine manually and letters are dumped into hoppers.*

**3** *High-speed canceling machines postmark mail as fast as the eye can follow it.*

**4** *Primary sorting is controlled by electropneumatics. Supervisor can select number of trays (5, 10 or 15) required for each sorting row.*

**5** *Card reader directs mail to secondary sort. Card is plastic sandwich of copper. At proper station, contacts on three openings operate pneumatic mechanism to move tray off main conveyor onto side tables.*

**Automatic sorting equipment at Washington P.O. changes the whole look of the Post Office.**

ITT

# What's New in ITV

Many exciting new uses for closed circuit television save time, life, health and money for industry, military, education and business.

- In the Antarctic, the Navy uses CCTV on a helicopter to picture ice conditions to an ice breaker following.
- A utility using ITV to observe water levels saved three salaries.
- In handling freight, ITV inspected cars and gondolas from a distance.
- Watching oil drilling or diving operations on the ocean floor from the surface.
- Checking factory operations for floors above from the main floor saved time and money.
- Guiding bulldozers run automatically in radioactivity areas from a safe distance.
- Stores and markets cut shoplifting and pilferage with ITV.
- Flame patterns in combustion chambers of engines and boilers may now be observed.
- Large organizations reach dealers through ITV in many cities for simultaneous meetings.
- Traffic flow through tunnels or toll bridges is checked and controlled.
- TV camera on factory roof scans large roofs for fires.

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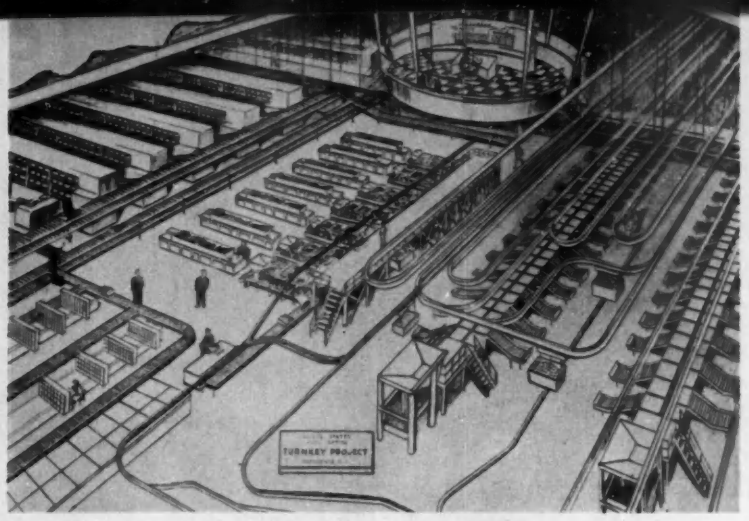
CIRCLE 20 ON READER-SERVICE CARD



*Artist's drawing of modern new post office being built Providence, R. I.*

Office, first step is to "cull" letters from big envelopes, newspapers, and packages. So far the job has been done by hand. The Post Office's Washington Laboratory is currently evaluating three different culling machines, will place orders for working models within the next year. Different designs have been developed by Emerson Radio & Phonograph Corp., American Machine and Foundry Co., and Intelex, a division of IT&T.

• **Sorting job**—After the mail is culled, sorting as to geographic destination takes place. Parcel post sorting machines are already in use in Baltimore and Washington. Packages are "hand-fed", addresses up, to an operator with small electronic keyboard, who, by pushbutton, directs each package onto its own tray on a moving belt and assigns the tray to one of its 32 possible classifications. The tray then dumps the package into the proper bin. With a machine, each operator can sort 40 packages a minute, a significant increase over hand sorting. By putting six sorting belts into the Washington Post Office, designers upped sorting capacity to 14,400 parcels an hour. Major suppliers of such gear include Webb (the Washington installation), Nelson Creller, (the Baltimore machines), Stewart-Warner Electronics and Aerojet General. The Post Office will order more sorters in coming months.

Letter mail is the worst of the manual sorting chore and becoming even more complicated. First the letter must be faced and canceled. Six new facer-cancelers in the Washington plant, made by Pitney-Bowes, Inc., handle 30,000 letters an hour—compared to the standard canceling machines whose rate is 6,000 per hour. And 25 more are on order for Detroit and Philadelphia. Three other new facer-cancelers, designed by Emerson, AMF, and Intelex, are being evaluated.

At Washington, the faced and canceled letters then flow into a keyboard sorting machine, where six operators direct 36,000 letters an hour to 300 different destinations. The Washington and Silver Spring, Md. offices use two European-made models, the "BELL' (Belgian) and "TRANSORMA" (Dutch), costing about $150,000 each. But these are relatively low-capacity machines.

Burroughs Corp. will put out its first sorter in June. It will cost less than the European units. Ten are on order, another 25 will be needed soon for Detroit and two for Flint, Mich.

Pitney-Bowes and Rabinow Engineering Co. of Takoma Park, Md., are also interested in producing sorters.

In spite of their speed, present-day sorters are still primitive in terms of realistic hopes for the future. In the laboratory stage are sorters using invisible "codes" read by electronic eyes. The ultimate—expected before too long: placing a code on a letter in Washington to guide it to its destination in, say, Phoenix.

• **Reading machines**—A still more advanced system—a machine that will electronically scan typewritten addresses—is under development by Intelligent Machines Research Corp. of Alexandria, Va. And, the experts say that sorters which will read handwritten addresses are near, too.

But complete automatic control, with clerks confined to pushbutton panels, is still a long way off, says R&D Chief Wade S. Plummer. For cities under 100,000, much mechanization is barred because of the enormous cost.

The greatly stepped-up program in the next couple of years will cut significantly into the mail traffic jam and provide the working experience for a real broadside attack.

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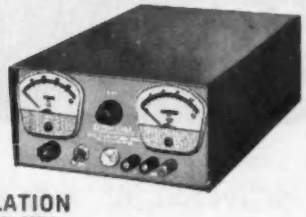

Model SC-18-2M

## 0.1% REGULATION STABILITY

| MODEL | DC OUTPUT VOLTS | DC OUTPUT AMPS. |
|---|---|---|
| SC-18-0.5 | 0-18 | 0-0.5 |
| SC-18-1 | 0-18 | 0-1 |
| SC-18-2 | 0-18 | 0-2 |
| SC-18-4 | 0-18 | 0-4 |
| SC-36-0.5 | 0-36 | 0-0.5 |
| SC-36-1 | 0-36 | 0-1 |
| SC-36-2 | 0-36 | 0-2 |
| SC-3672-0.5 | 36-72 | 0-0.5 |
| SC-3672-1 | 36-72 | 0-1 |

## 0.01% REGULATION STABILITY

| MODEL | DC OUTPUT VOLTS | DC OUTPUT AMPS. |
|---|---|---|
| SC-32-0.5 | 0-32 | 0-0.5 |
| SC-32-1 | 0-32 | 0-1 |
| SC-32-1.5 | 0-32 | 0-1.5 |
| 2SC-32-1.5 | 0-32 | 0-1.5 |
| DUAL OUTPUT | 0-32 | 0-1.5 |
| SC-32-2.5 | 0-32 | 0-2.5 |
| SC-32-5 | 0-32 | 0-5 |
| SC-32-10 | 0-32 | 0-10 |
| SC-32-15 | 0-32 | 0-15 |
| SC-60-2 | 0-60 | 0-2 |
| SC-60-5 | 0-60 | 0-5 |
| 2SC-100-0.2 | 0-100 | 0-0.2 |
| DUAL OUTPUT | 0-100 | 0-0.2 |
| SC-150-1 | 0-150 | 0-1 |
| SC-300-1 | 0-300 | 0-1 |

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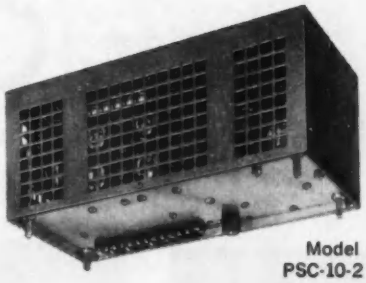

Model PSC-10-2

## 0.02% REGULATION STABILITY

**COMPACT PACKAGE TYPE**

| MODEL | DC OUTPUT VOLTS | DC OUTPUT AMPS. |
|---|---|---|
| PSC- 5-2 | 0- 7.5 | 2 |
| PSC-10-2 | 7.5-12.5 | 2 |
| PSC-15-2 | 12.5-17.5 | 2 |
| PSC-20-2 | 17.5-22.5 | 2 |
| PSC-28-1 | 22.5-32.5 | 1 |
| PSC-38-1 | 32.5-42.5 | 1 |

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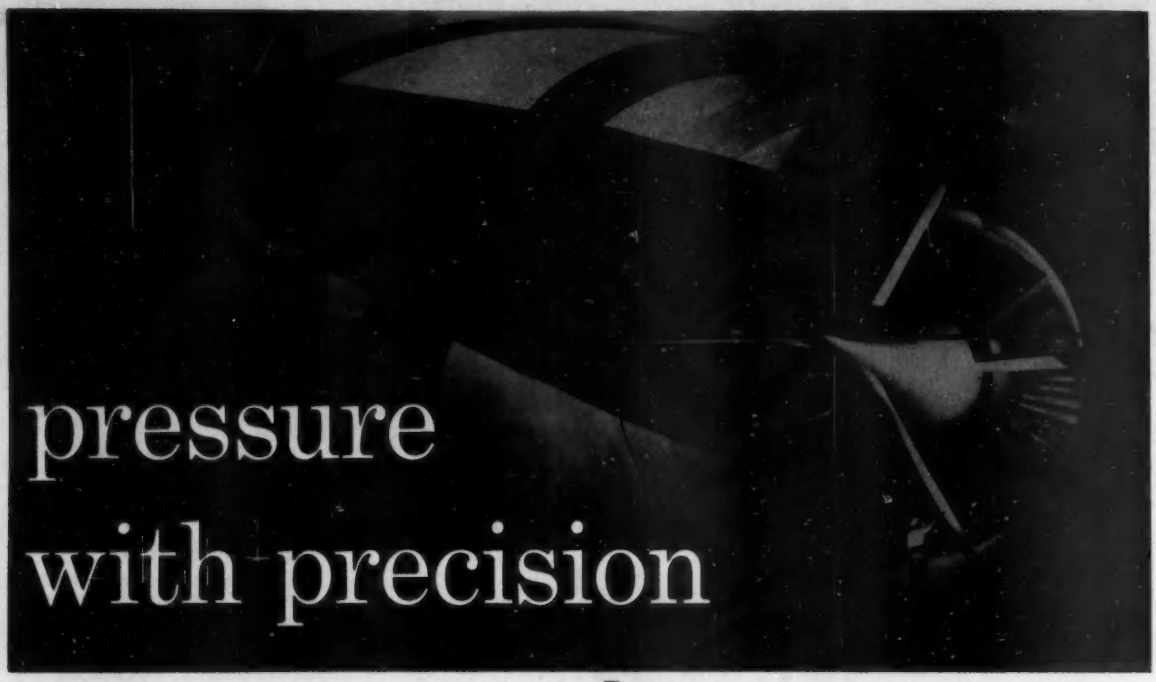

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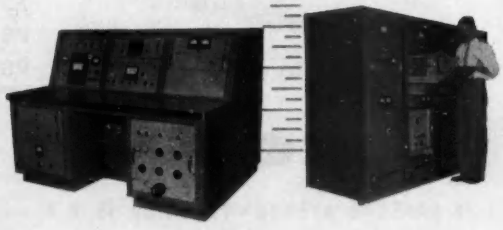
Pressure transducer calibration system controls and measures pressures from 25 pickups in ranges from 1.5 to 500 psi. Linearity, hysteresis, zero, and sensitivity characteristics are determined at a specified temperature in 2½ minutes.



Propellant Utilization System Exerciser checks missile system performance by generating precise pressures for fuel and oxidizer channels at preselected points. Twenty-one similar systems are now in use at missile test sites.

# Spotting Automotive Troubles —Automatically

**Applying computing-control to the automatic inspection of combat vehicles may lead to a revolution in automobile servicing. A new project at Frankford Arsenal is aimed at instrumenting the thinking of a good mechanic.**

PHILADELPHIA—
At Frankford Arsenal last month, engineers in the Research & Development Engineering Support Div. waxed enthusiastic over a new project, one which stands a prime chance of revolutionizing the automotive industry's toughest problem—servicing. Under the direction of Anthony Bruno, chief, R&D Systems & Components Div., ordnance engineers started a study of a computing-control checkout system that will automatically inspect the engine, transmission, suspension, and turret drive of Army tanks. When completed, it will take trouble-shooting decision-making out of the hands of Army mechanics, put it into the unprejudiced workings of a digital computer.

Automotive vehicle inspection, says E. P. McMenamin, of the arsenal's R&D Mission Management Office, is a natural outgrowth of the work Frankford engineers have done in the automatic checkout of artillery fire-control systems and missile systems. It was prompted by the high cost of keeping Army vehicles running.

• **Isolate the failures**—Frankford's approach is based on a philosophy developed for two earlier checkout programs, TRACOS (Transistorized Checkout for Systems) and TRACT (Transistorized Checkout Tester—for components). The technique: interrogate the vehicle with a number of stimuli, then use logic and computer circuitry to isolate specific faults. In some cases, components are evaluated without direct measurement. With the inspection equipment, ordnance engineers hope to be able to determine malfunction without tearing down the vehicle.

Frankford engineers have three major problems to solve in building the first prototype. First—and possibly toughest—is deciding what kind of information will be required to determine malfunction. To help, specialists from the Ordnance Tank & Automotive Command will supply a background of field experience. And design engineers will visit depots to pick up how a repairman detects trouble.

Once it has been decided what information is required, the second task is getting it. Frankford plans a survey of all available measuring instruments and transducers, may have to develop some special ones. The transducers must be easy to apply to a vehicle—through such means as alligator clips or magnetic holds.

Finally, a computer subsystem compatible with the information gathering subsystem has to be built.

• **Signs of trouble**—Getting sufficient information about automotive ills and their symptoms is a king-sized job because so much of auto trouble-shooting is art rather than science. An automotive transmission is typical. Symptoms of transmission breakdown—or impending breakdown—will have to be categorized. Suppose, for example, noise turns out to be a good sign of trouble. Then engineers will have to determine how much noise is serious trouble, evolve some method of recording the noise in a form that can be stored in the computer memory.

Once engineers know what kind of information has to be obtained, how much, and in what form, they can start looking for transducers and instruments to supply it. In the transmission problem, for example, it is likely that small microphones or stethoscopes will serve as transducers. Other possibilities that look promising for other diagnoses: accelerometers, thermocouples, strain gages, eddy currents, magnetic field measurements, and ultrasonics.

• **Fitting in the computer**—Concerned with making the computer portion of the system compatible with the information system is A. Chalfin, Frankford project engineer. Speed, says Chalfin, is the biggest problem. The information system is slower than the computer; transient phenomena in measurements put a limit on speed.

In Frankford's concept, the computer is multipurpose: it will sequence the test, accumulate test data, analyze it for signs of trouble, decide what parts should be replaced, then print out the results for the mechanic.

Chalfin cites three advantages of computing-control over a comparator approach to automatic checkout—an approach in which the measured variables are merely compared to standards preset into the system. First is flexibility. Using a computer, the inspector can stop a test, go back and start over simply by telling the computer to do this. And it is relatively easy to make changes in the test procedure of the computing-control system; it's done by inserting a new program into the machine. Many comparators use wired programs, so that a change means a new wiring job.

Second advantage is smaller size. A comparator system requires duplication of circuits and equipment; the computer uses the same circuitry and logic for comparison and analysis.

Still another advantage of the computing approach is inherent built-in checking of data. In comparator systems, most checking circuitry has to be supplied as a supplement.

To check out a missile system, Chalfin estimates, a storage of 1,000 words (36 bits per word) is adequate for the instructions for programming the test and analyzing the data. He guesses it will take at least 2,000 words to do the same thing for the vehicle.

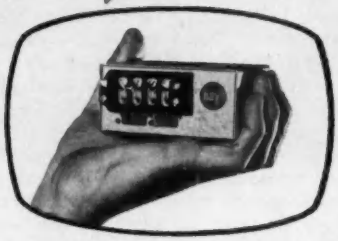
In the prototype inspection equipment, Frankford plans to use a general-purpose computer (either Jukebox, a small, militarized, digital machinery developed for the ground launching of the Redstone missile, or FADAC, an even more sophisticated general-purpose machine for artillery fire control). Both machines were developed at the

# RAMBLINGS ON INSTRUMENTATION

For those of you who missed our commercial on the EARLY, EARLY SHOW (4:00 a.m. EST) last February 29th, we herewith reprint a few excerpts from the videotape. The musical background (provided by a glockenspiel and cash register) must, of course, be imagined.

Phil Sprague Jr. President

ANNCR.: Oh, hello there. Say, friends, if you've been nervous, irritable, out of sorts lately...it may be due to nagging dry cells in your DC Voltage Supply. Well, now you can say good-bye to calomel calibrations for keeps with the amazing new...



...HDCCVS! (Hdccvs is short for Hays DC Constant Voltage Supply, friends.) And here it is—the thinking man's DC voltage supply. Just plug it in to any 115-volt AC outlet enjoy cool, clean, accurate DC voltage...volt after volt after volt.

You can use the new Hays DC Constant Voltage Supply unit with practically any potentiometer type instrument...and put those dry cells back in your mother-in-law's hearing aid.

Imagine!—no more stabbing shoulder pains from lugging suitcase loads of batteries to the Bureau of Standards! No more calomel cells to pamper and polish!

Now, for you eggheads, the stability of this money-saving little rascal is ±.05% for ±20% supply voltage variations; ±.08% maximum drift over 10,000 hours of operation (readjustable); and ±.0045% max./°C: change in ambient temperature. Is that clear?

The Hays folks will be glad to bombard you with all the facts. Just drop them a postcard with your name and address. And tell 'em where you heard about it, friends. Now, back to our movie to see how Dustin Farnum is making out against those redskins...

CIRCLE 23 ON READER-SERVICE CARD


## WHAT'S NEW

arsenal. The computer has to serve as a controller as well as a calculator.

Because of the extensive control functions of the computer, Chalfin is also investigating how a digital differential analyzer might replace a gp machine. The DDA's incremental method of operation lends itself to control, but there's some sacrifice in arithmetic capability.

• **About $1 million**—The first checkout system, which may cost about $1 million, will prove feasibility. If the unit is a success, Frankford has some even more exciting plans. The ultimate goal, says Mission Manager McMenamin, is an automatic checkout *and prediction* system for vehicles, one that will answer the question, "Will this vehicle last another 100 hours in combat?" To do this, McMenamin sees need for a project devoted to collecting histories of vehicle wear-out so that life curves can be stored in a computer memory. As the inspection equipment checks out the vehicle, it will also determine how much is left in each component.

Still another possibility is a standard checkout system for all ordnance equipment, one system that will check both missiles and vehicles (though with different transducers, program, and instrumentation).

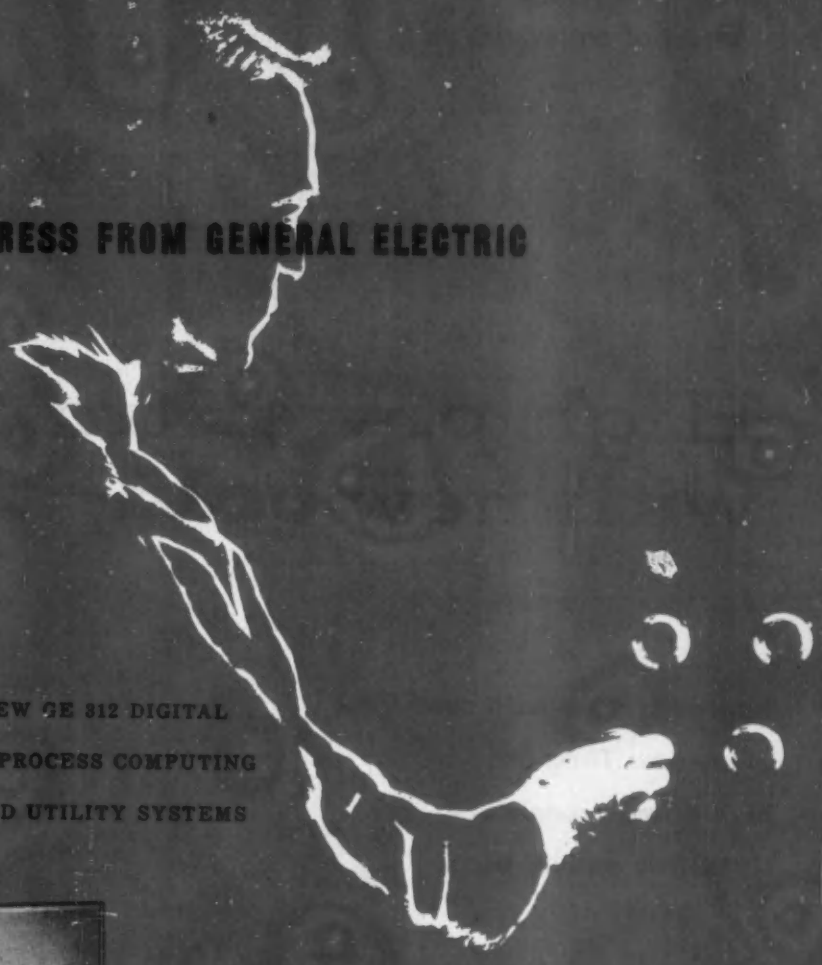
And for the civilian automobile market, automatic checkout inspection offers even more promise. Anthony Bruno thinks that eventually automatic equipment, programmed to handle the less rigorous inspection of civilian vehicles, could be built at a cost that would make it economic for car dealers and large garages to buy or rent them. A target selling price: $30,000.

• **"Replace the following:"** Here's how Bruno envisions the new equipment will be used. First a vehicle will undergo a visual inspection to identify such obvious faults as a bent chassis, torn tires, smashed headlights, badly cracked engine block, or missing floor boards. Then the engine will be tuned up sufficiently to make it run. Object of this step is to eliminate vehicles whose engines have frozen solid with rust during outdoor storage. Finally, the vehicle will be driven onto a dynamometer, transducers and instruments attached, and with the engine running, put through its paces by the automatic checkout equipment.

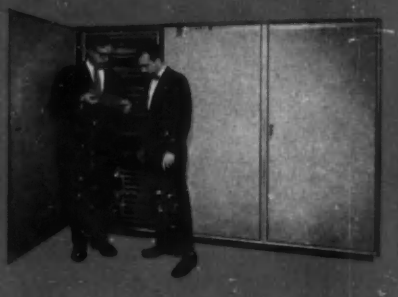
At the conclusion of the test, the equipment will print out the net results of the test, an instruction card for the mechanic reading: "Replace the following parts".

—Lewis H. Young

# COMPUTER PROGRESS FROM GENERAL ELECTRIC



## ANNOUNCING THE FLEXIBLE NEW GE 312 DIGITAL CONTROL COMPUTER FOR ON-LINE PROCESS COMPUTING APPLICATION IN INDUSTRIAL AND UTILITY SYSTEMS



GE 312 DIGITAL CONTROL COMPUTER

Newest member of a distinguished family of General Electric computers, the GE 312 *transistorized* DIGITAL CONTROL COMPUTER has been especially designed for process control, data logging, and data processing requirements imposed by industrial and utility operation.

• "Big Machine" features—moderate in cost • Expansible memory capacity • Easily programmed • Advanced programming aids available • Rugged construction for industrial application • Off-line operation as a general purpose computer

Request brochure CPB-36. For more information on computers, computing control and automation, contact your nearest General Electric Apparatus Sales Division Office, or write to: Computer Department, Room 330 General Electric Company • Deer Valley Park • Phoenix, Arizona.

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**GENERAL ELECTRIC**

FOR FIGURES IN A HURRY—FIGURE ON A GE COMPUTER

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CPA-20 B-40

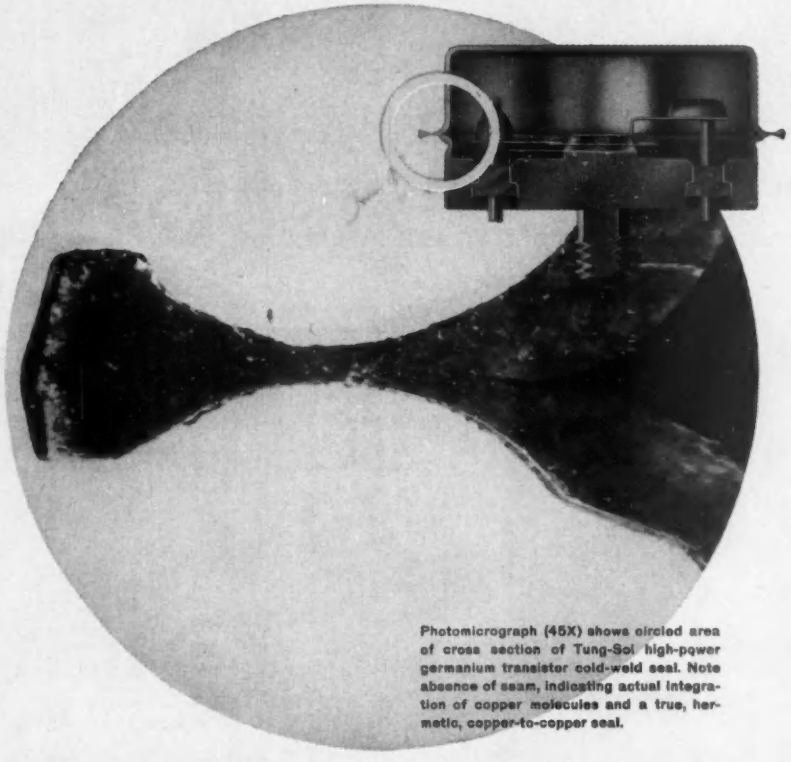
*Tung-Sol moves ahead!*

# Now

# High power transistors with new **cold-weld** seal

**Improved cold-weld seal gives new Tung-Sol high-power transistors three-way quality boost**

- True hermetic, copper-to-copper seal improves transistor thermal characteristics.
- Elimination of heat-damage, heat-caused moisture and "splash" increase reliability.
- Vacuum-tight, moisture-proof cold-weld seal lasts even through "breathing" over long life operation.



Photomicrograph (45X) shows circled area of cross section of Tung-Sol high-power germanium transistor cold-weld seal. Note absence of seam, indicating actual integration of copper molecules and a true, hermetic, copper-to-copper seal.

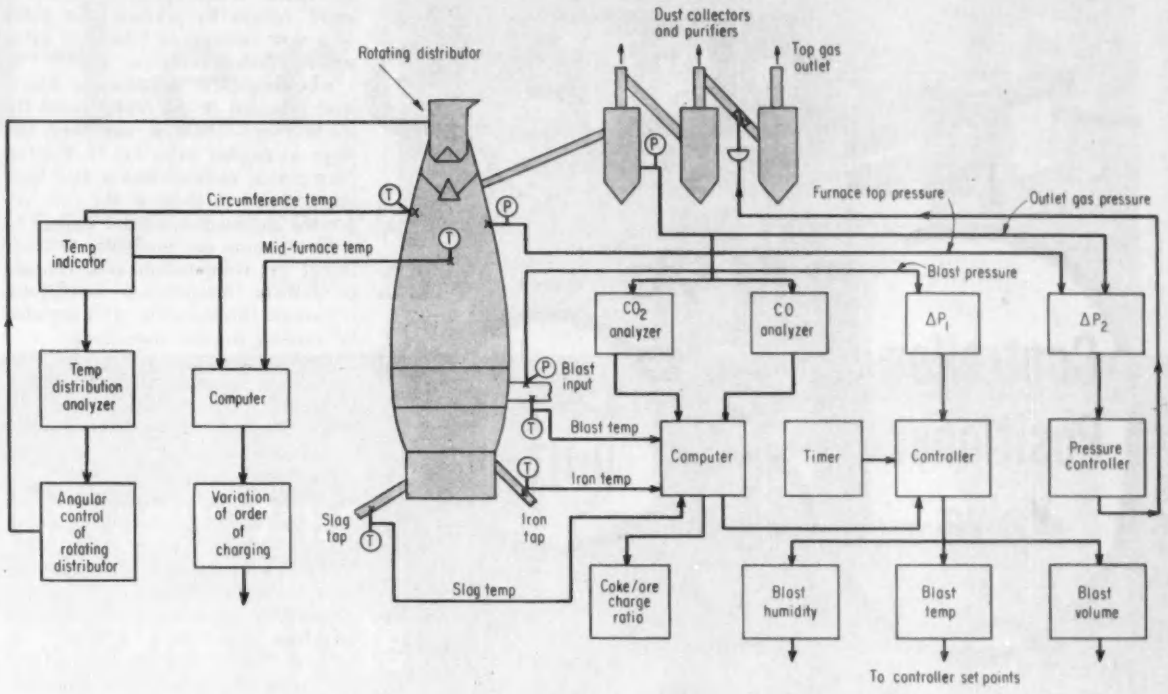
Once again Tung-Sol shows the way. Now, for the first time, Tung-Sol brings designers high-power germanium transistors with quality benefits of the advanced cold-weld seal.

The new Tung-Sol types feature a stud-mounted package and maximum collector current of 13 amps. Military environmental tests combine with the radioactive gas leak detection test to assure maximum reliability.

Technological advancements such as this keep Tung-Sol ahead of the field. For full data on the new high-power switching transistors . . . to meet any need with the latest in transistor design and efficiency, contact: Semiconductor Division, Tung-Sol Electric Inc., Newark 4, New Jersey.

TUNG-SOL®

**EUROPEAN REPORT**




# Soviets Push Blast Furnace Control

Control systems installed over the past five years have raised Soviet blast furnace efficiency by 10 percent, cut fuel bills by 2 percent annually. The savings were reported last month by the Soviet Central Automation Laboratory of the Soviet Energotschermet combine, which is charged with implementing blast furnace control systems. The report also stated that 80 percent of large furnaces are equipped with humidity control of the blast air in addition to blast heat control; 67 percent use three-term controllers to increase throat pressure.

The Russians have, according to the report, both a short-range and a long-range approach to the problem of blast furnace control.

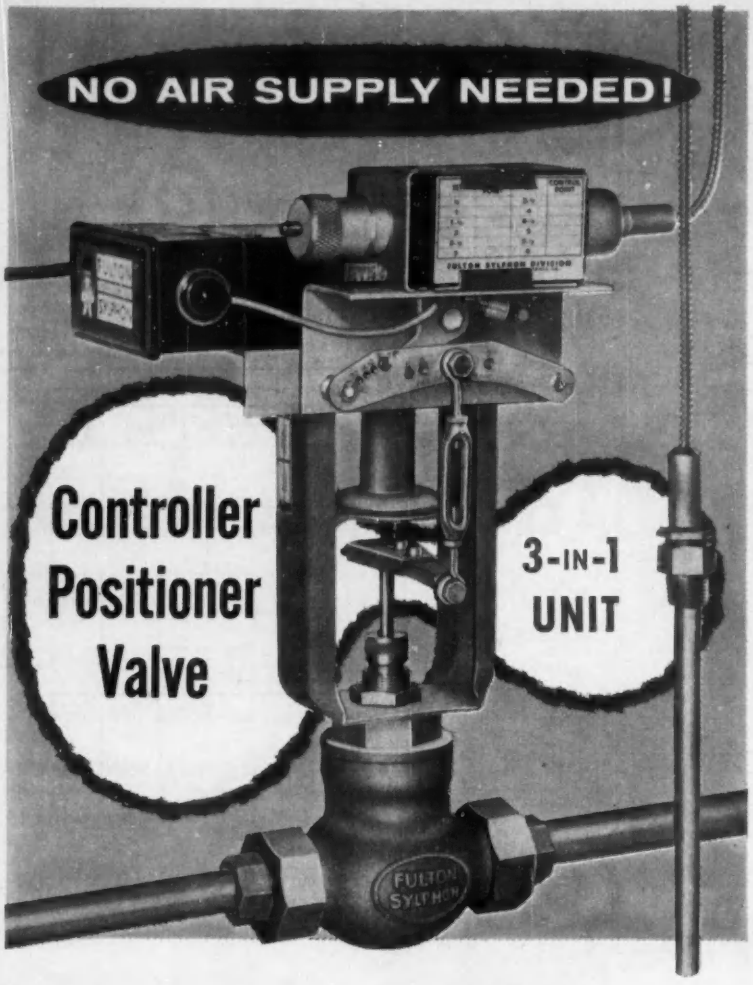
For the short range, the Soviets are applying elaborate automatic data-logging systems, known throughout Russia as "foremen's friends". Computer-type logic circuits, using solid-state devices and transistors, analyze incoming furnace performance data against preset instructions. Variations from the rule book illuminate output panels that give the foreman descriptive instructions of the corrective action required. Each procedure is compatible with the Soviet's rigid standardization of furnace operation and is the subject of detailed instructions.

• **Automatic control**—In the long run, the Soviets are striving for full automatic control. The diagram above shows how. By full control, the Soviets mean directing four main functions: 1) furnace heating, determined from continuous analysis of combustion products; 2) input blast to the furnace, controlled from differential pressure measurements between top and bottom of the furnace and dust collectors; 3) order variation of loading coke and ore charges to the furnace, dependent on the temperature profile across the furnace; and 4) quantity of variation of charge loaded, to maintain even circumferential temperature distribution.

Breaking away from conventional furnace techniques, the Soviets are putting thermocouples around the circumference of the furnace walls to actually control the loading of the charge. High temperature spots in a distribution plot indicate that the charge fills the furnace incompletely at these points, allowing rising blast gas to raise the wall temperature.

Location of minimum and maximum temperature points position the rotating charge distributor so that double charges of coke and ore are deposited in hot spot areas and reduced charges in minimum temperature areas.

In addition, to obtain a radical temperature profile, thermocouple probes travel across the furnace diameter




**Complete, Pre-assembled Electric Modulating Unit Controls Process Temperatures at Less Cost!**

Right on the heels of the recently introduced FultroMatic air-actuated unit, Robertshaw engineers perfect this electrically operated version, the FultroLectric.

This low-cost combination Controller-Positioner-Valve provides modulating control of critical processes at about one-half the cost of two- and three-unit systems.

- **Dependable accuracy:** element responds to minute changes
- **Positive valve positioning:** no overshoot
- **Adjustable proportional band** easily changed on the job
- **Simplified settings:** easily reproducible
- **Field reversibility** for changing control action
- **Easy to install:** place valve in line, mount bulb, connect power
- **Low maintenance:** rugged design for trouble-free service

For complete details and specifications, write for Bulletin JW-756

Robertshaw-Fulton
CONTROLS COMPANY

**FULTON SYLPHON DIVISION • Knoxville 1, Tennessee**

**CIRCLE 26 ON READER-SERVICE CARD**



below the surface of the charge. A two-speed winch provides either a rapid travers to position the probe or a slow continuous travers to measure the distribution.

• **Loading-cycle variations** — Excess heat recorded in the center varies the loading cycle of the coke and ore skips to deposit extra ore in the furnace center, switches in a second loading program to increase the coke deposited around the furnace walls.

Continuous gas analyzers measure throat gas composition and, coupled to furnace temperature conditions, determine the coke/ore ratio required for existing furnace conditions.

Another control loop regulates blast humidity, temperature, and volume. It operates on a fixed-time cycle. A timer switches in three controllers in turn for each variable.

First fully automatic system is scheduled to go into operation this year. But lack of adequate instrumentation—especially for gas analysis and level measurement of the furnace melt —may delay operation.

• **Another approach**—At the Donetz Industrial Institute, engineers are working on a different approach. They are trying to maintain a continuous mass balance between materials fed in and emerging from the furnace. Mathematical representations are being studied to obtain the operational equations that can be programmed into a computer. The computer would then adjust controller set-points and provide data on the rate of charging required.

Three Soviet furnaces are already using fully automatic charging. In one, the scale car is automatically loaded with known weights of coke and appropriate ores, then automatically discharged into the skip hoist.

—Derek Barlow

### European Bits

New transistorized character reader can scan 100,000 figures per sec. Built by EMI Electronics, Ltd., the unit will be incorporated in an experimental banking system soon this year. Each number is scanned by a light beam and the reflections are picked up photoelectrically.

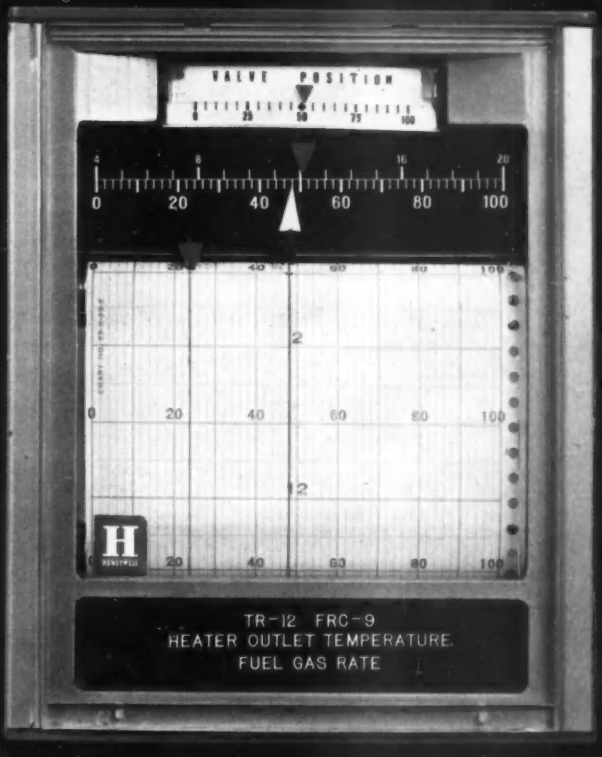
•

Soviets plan translating machine to convert intricate Chinese characters into the Cryllic alphabet. The machine will be similar to the one already developed by the Russians for English to Russian translations.

# Here it is!

## Honeywell's new *ElectriK Tel-O-Set** system

...the only true two-wire system for electric process control!




*No line power connections in the field.* The *ElectriK Tel-O-Set* system requires no external power at any field-mounted device and uses only two wires between it and the control room. These two wires form a series circuit that carries the measurement or control signal as well as the system's power. The only line power connection is made at the receiver.

Two-wire transmission sharply reduces installation costs. Add this to the fact that the *ElectriK Tel-O-Set* system's d-c transmission eliminates the need for shielding the wires, and you have the simplest, most economical installation possible.

*Trade name, Minneapolis-Honeywell Regulator Company

H HONEYWELL

**COMPARE *ElectriK Tel-O-Set* WITH ANY OTHER ELECTRIC CONTROL SYSTEM!**

# Here it is!

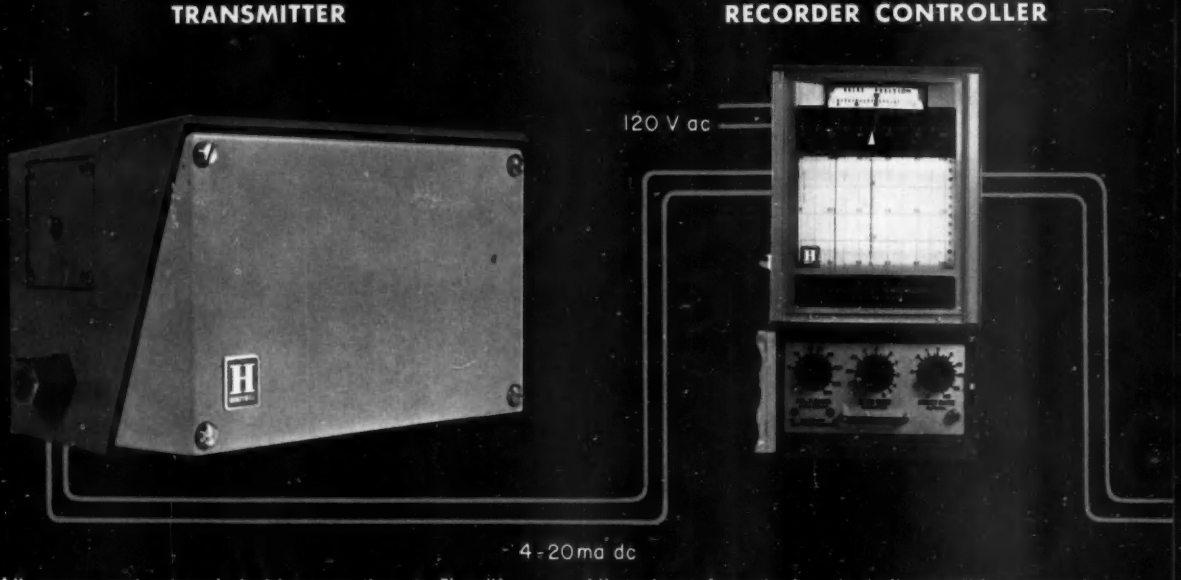
## the new *ElectriK Tel-O-Set* system...newest advance

### *A complete, integrated line...*

Control *any* industrial process with the *ElectriK Tel-O-Set* system. It has been designed as a complete system, rather than as a collection of individual instruments. The line consists of 22 major units which permit local and centralized data presentation, adjustable cascade control, ratio control, and many other auxiliary functions. *ElectriK Tel-O-Set* transducers make the line completely compatible with your present pneumatic instruments.

### *...built for industry*

Die-cast aluminum cases and stainless steel components are used throughout the line to withstand the rough handling and demanding environments of industrial applications. Standardized components, together with extensive use of quick-connect and plug-in design, mean ready interchangeability of parts, reduced spare parts inventory, easy maintenance. The modular, or "building block" concept is employed throughout for maximum flexibility, with all components needed for a particular function housed in a single case.




All process and external electric connections to *ElectriK Tel-O-Set* field-mounted transmitters are entirely isolated from inside the case . . . to permit installation without the need for instrument department supervision.

All receivers, from single-point indicator without control to two-pen ratio-cascade control station, are housed in the same case and all use the same panel cutout of 5½ x 6 inches. Controllers can be mounted with adjustments in front or back of panel.

**Choice of three cases**

for field-mounted *ElectriK Tel-O-Set* units: Weatherproof (left) for Division 2 locations; relay rack (center) for mounting four abreast in a 19-inch rack, and explosion-proof (right) for Division 1 locations. All are completely transistorized and have quick-connect electric and pneumatic plugs.

**COMPARE *ElectriK Tel-O-Set** WITH ANY OTHER ELECTRIC CONTROL SYSTEM!**

## in industrial process control

### ...this is how it works

The basic *ElectriK Tel-O-Set* system consists of a transmitter, receiver, controller and final control element, usually a valve. The transmitter measures any process variable, translates it into a standard 4 to 20 milliampere direct current signal, and transmits to the receiver through a pair of copper wires. The receiver indicates or records the signal in terms of the actual value of the process variable, compares it with a predetermined set-point, and sends the difference to the controller as an error signal. The controller then converts this into a corrective 4-20 milliampere output to operate the control valve—again transmitting over a single pair of copper wires.

**VALVE OPERATOR**

4-20 ma dc

All *ElectriK Tel-O-Set* field-mounted units . . . whether transmitter, transducer, or valve actuator . . . operate at ambient temperatures of —40 to 150°F. They all work on the same force-balance principle and use many similar components.

## SYSTEM COMPONENTS

### Transmitters

Process pressure to current (PP/I)

Differential pressure to current (Δ P/I)

Millivolt to current (MV/I)

### Recorders

Single or two-pen recorders

Single or two-pen recording controllers with control, including simple cascade, on one pen

Two-pen recording controllers with ratio or cascade control on one pen

### Indicators

One pointer, with or without control

Milliammeter, with or without manual loading

### Controllers

Two mode and three mode

### Final Control Elements

Current to pressure (I/P) valve operator

Electro-pneumatic positioner

Electro-hydraulic actuator

### Transducers

P/I: 3-15 psi to 4-20 ma dc

I/P: 4-20 ma dc to 3-15 psi

I/F: 4-20 ma dc to frequency

F/I: frequency to 4-20 ma dc

### *Transistors . . . for greatest reliability*

Transistors are used throughout the *ElectriK Tel-O-Set* line to assure utmost dependability. Since transistors require no power for operation other than that of the signal being transmitted, no external transmitter power is required. The 4-20 ma d-c signal used in the system is consistent with optimum transistor performance . . . eliminates line resistance difficulties.

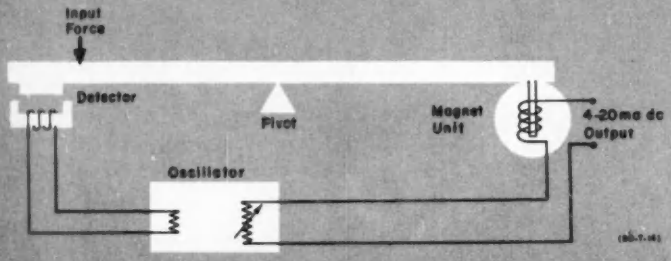
**Honeywell**

First in Control

# Here it is!

## *The high accuracy and swift response you want ... assured by this simple force-balance principle that underlies all* ElectriK Tel-O-Set *instruments*

All *ElectriK Tel-O-Set* transmitters, receivers and final control elements operate on a simple force-balance principle . . . a principle that increases accuracy and dynamic response by decreasing hysteresis effects and sensitivity to ambient conditions.




The force balance circuit has four basic parts—a beam, detector, oscillator, and magnet unit. Input force deflects the pivoted beam. This changes the gap in the detector, which consists of two pieces of ferrite; one mounted on the beam, the other on the chassis. As the spacing between the two pieces of ferrite changes, there's a proportionate change in the inductance of the coil which is wrapped around the stationary portion of the detector. When this happens, the oscillator changes its output accordingly, between 4 and 20 milliamperes. This current is fed back to the magnet unit, producing a force on the beam that is equal and opposite to the input force, limiting full-scale beam motion to approximately one-thousandth of an inch.

### *Simplified maintenance*

The use of common parts like the basic detector, oscillator, and magnet units throughout the *ElectriK Tel-O-Set* line is an enormous maintenance advantage—as is the extensive use of quick-connect and plug-in components. All adjustments are quickly and easily accessible, either externally or just inside the case. Even the explosion-proof housings have external zero adjustments. Most process and external electrical connections are of quick-connect design, and are entirely isolated from the inside of the various cases . . . so that your installation crews can install the instruments without standby supervision.

**COMPARE *ElectriK Tel-O-Set*** WITH ANY OTHER ELECTRIC CONTROL SYSTEM!**

Get complete details from your nearby Honeywell field engineer. Call him today . . . he's as near as your phone.

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21 Penn St., Fall River, Mass.

**Honeywell**

First in Control

FR 2800 227M

# Russians Sharpen Pencils to Justify the Seven-Year Plan

***Translations of current Soviet literature show a sharpened interest, in the new seven-year plan, in the economic justification of automatic production. Not so clear is how much Soviet economics is meaningful and how much is arithmetic mumbo-jumbo designed to sell the program.***

It isn't news that the Soviet Union has launched an ambitious seven-year plan to boost industrial output by 80 percent and consumer-goods production by 65 percent—by 1965. But not so well-known is the concentrated effort behind this program to justify in economic terms every step that is being taken. Last month, a Belgian professor, Max Ajnbinder, surveyed current Russian literature on the subect, found the Soviets have evolved a complex mathematical approach to decision making.

Much of Soviet hopes, Ajnbinder deduced, are based on an ability to boost productivity of labor, primarily through the installation of automatic controls. The objective: a 45-percent increase in productivity of the industrial worker by 1965. To measure how they are doing—and to help decide what further steps to take—the Soviets have evolved some new concepts, are using some established techniques of capitalism—with some twists.

• **Three keys**—During his study, Ajnbinder found the Soviets rely on three key mathematical criteria:

▶overall productivity increase, computed from the output increase and ratio of nonproduction workers to production workers.

▶manufacturing cost reduction, resulting from output increase and change in fixed capital investment.

▶comparison of capital payoff between automatic and nonautomatic processes.

It's not crystal clear how much of this mathematical approach is really useful, and how much is mathematical mumbo-jumbo designed for propaganda purposes. Although, the Soviets profess real concern for justifying automatic installations economically, the driving force in the seven-year plan is higher production. Automatic control systems are installed, Ajnbinder infers, primarily to raise production, not to effect financial savings.

Such a philosophy shades the whole Soviet approach to justification. For example, any comparison between automatic control and nonautomatic systems has to be based on the output of the higher-production automatic system. Costs associated with the nonautomatic system are corrected to this higher output.

• **Putting numbers on productivity**—Because increasing productivity is so important, Russian economists have come up with a complex formula for measuring it after an improvement has been made:

$$P_e = \frac{(p-1)}{a + (100-a)p/100} \times 100$$

where $P_e$ is overall productivity increase
$p$ is production as a percent of initial production
$a$ is the ratio of nonproduction workers to production workers

Applying the formula to a couple of specific cases turns up a surprising view of productivity. If an automatic control installation boosts production 20 percent in a plant whose ratio of nonproduction workers to production is 20 percent, the formula determines that the increase in productivity is 3.45 percent. If another installation boosts production 20 percent in a plant whose ratio of production workers to production is 60 percent, the increase in productivity becomes 11.1 percent. That means that a big increase in productivity, on paper, could be misleading: a plant loaded with nonproduction workers would make the biggest gains in productivity. Further, the overall operation could be highly inefficient because of these nonproduction people—and the formula would never show it.

Included in this formula is the inference that the number of production workers is being reduced, not that the ratio is being increased by employing nonproduction workers.

To combine productivity increase and capital investment, the Russians have devised an "efficiency factor". Here is one example of how it works.

• **An extra blast furnace**—Automatic control, Russian studies have shown, can increase productivity of blast furnaces 7 to 10 percent. Therefore, if 12 existing furnaces are equipped


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Versatile, reliable, the M-10 is suitable for many applications where low level DC amplification is required. May operate from either current or voltage source and provide either current or voltage output with proper shunts.

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The M-10 is ideal for use with 0-1 MA recorders. High output impedence prevents excessive damping. A trim adjustment is provided to calibrate the combination to ½%. Linearity is better than ½% for the amplifier. (Combination usage shown is with Esterline-Angus 0-1 MA Recorder)

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## WHAT'S NEW

with such control, the Soviets gain the equivalent of an extra blast furnace. To calculate the efficiency factor, the Russians relate the cost of the blast furnace (100 million rubles*) to the cost of the control for 12 furnaces (6 million rubles at 500,000 each): 100:6 or 16.6. The efficiency factor means that one ruble invested in automatic control equipment increases production as much as do 16.6 rubles spent in new blast furnaces.

Still another tool, Ajnbinder found, is a formula to determine payout time of a control installation. The formula:

$$T = \frac{I_1 - I_2}{(P_2 - C_2)O_2 - (P_2 - C_1)O_1}$$

where $T$ = payoff time in years
$I_1$ = capital investment for manual production
$I_2$ = capital investment for automatic production
$P_1$ = unit selling price with manual production
$P_2$ = unit selling price under automatic production
$C_1$ = unit cost under manual production
$C_2$ = unit cost under automatic production

To control engineers familiar with the payout method of justifying control systems (CtE, Dec. '58, p. 65), the above formula strikes a responsive note. Analysis shows it is really just a complex way of determining the ratio of investment to savings.

One application of this formula, Ajnbinder reports, sheds an interesting light on how frequently the Soviets ignore any relationship between costs and price. In an agricultural implement plant, the installation of new controls upped production from 37,000 to 70,000 units per year, while reducing the work force from 86 to 48. The works selling price remained the same—1.85 rubles—but production costs dropped: prior to mechanization, production costs were more than the selling price, 2.0 rubles; they were cut to 1.57 rubles by the automatic equipment. The payoff time for the installation was 1.4 years.

All this emphasis on justification, apparently backed up by case histories, indicates that the Russians may have a new approach to increased production. Sophisticated automatic controls are replacing brute force, in which production is boosted by building more plants and putting more people to work.

* Actual purchasing power of the ruble is quite arbitrary. For example, the official exchange rate is four rubles to the dollar while the tourist rate is 10 rubles to the dollar.

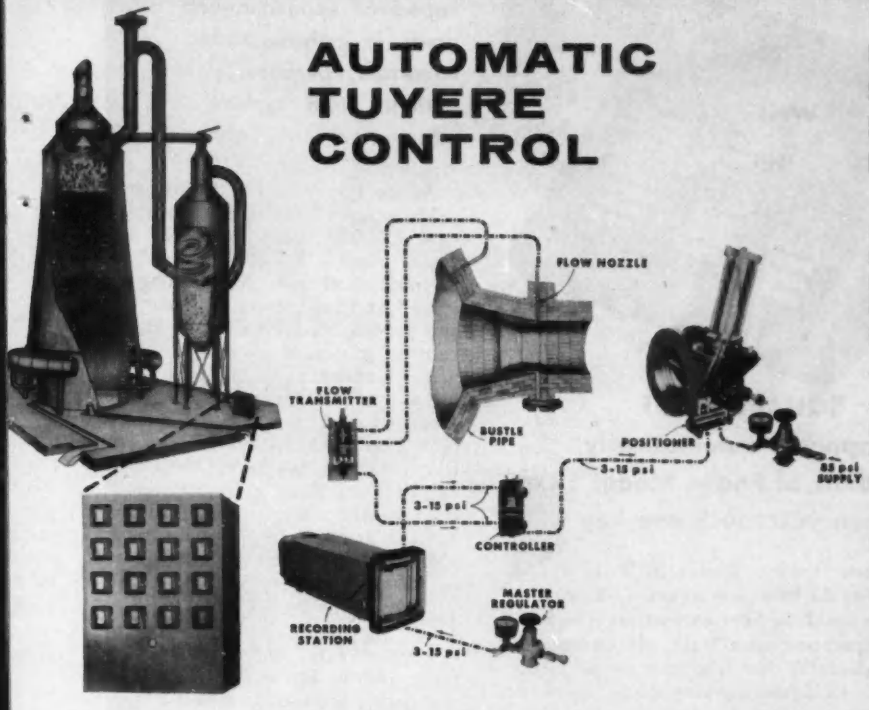
POSITIVE CONTROL OF MATERIALS IN MOTION

METERS FEEDERS CONTROLS

# B-I-F INDUSTRIES

BUILDERS-PROVIDENCE • PROPORTIONEERS • OMEGA

PROCESS CONTROL SYSTEMS NEWS




## AUTOMATIC TUYERE CONTROL

**AUTOMATIC EQUALIZING OF AIR FLOW THROUGH TUYERES ELIMINATES FURNACE HOT SPOTS, BURNED LININGS, EXCESSIVE FINES CARRY-OUT, AND HIGH BLOWING COSTS . . . INCREASES FURNACE LIFE!**

A blast furnace *charge* is temperamental! Temperature and burning rate must be closely controlled or destructive *hot spots* burn the linings, "channeling" causes excessive fines carry-out as well. AUTOMATIC TUYERE CONTROL has solved these problems.

Automatic Tuyere Control maintains a balanced flow of *blast* air through each of the 12, 16 or 20 blast nozzles comprising a particular battery of Tuyeres. An 1800° F. hot blast of enriched air is blown into the base of the blast furnace to control the temperature and burning rate of charge and to provide the oxygen needed to burn the coke. Blast air is fed to Tuyeres through a large duct (bustle pipe) encircling the lower periphery of furnace. System constantly follows furnace conditions . . . throttling or increasing air flows for optimum operation.

### B-I-F SIMPLIFIES CONTROL SYSTEM . . . REDUCES INSTALLATION COSTS . . . INCREASES EFFICIENCY

B-I-F Industries' simplified control system incorporates a unique flow nozzle and minimum control equipment to make it the lowest cost, fully automatic "complete package" system available. Basic components include a Flow Nozzle, a Balanced Flow Transmitter, a stacked diaphragm Controller, a strip chart Recording Control Station, a 4-way Valve Positioner and a ceramic-lined Butterfly Valve.

Control stations are all cascade control systems. All Tuyere Controllers receive same "master" set point in normal operation . . . assuring equal flow through all Tuyeres. If a Tuyere "channels" and causes a flow increase during operation, the Controller throttles the Butterfly Valve to prevent a "run-away" Tuyere. Conversely, should a Tuyere become plugged, the Controller opens the Butterfly Valve to permit more air to enter the Tuyere. If the fully-open Butterfly Valve cannot deliver its share of air, the bustle pipe pressure increases automatically . . . the increased pressure is made available at the plugged Tuyere . . . and equal flow is maintained through *all* Tuyeres.

The "master" signal control used on the B-I-F system prevents unnecessarily high bustle pipe pressure and resultant high blowing costs. System follows furnace conditions and automatically trims master set point to keep all valves as nearly wide open as possible, thereby keeping throttling action and blowing costs at a minimum.

For complete data on this or other process control systems, write **B-I-F Industries, Inc., Industrial Sales, 528 Harris Avenue, Providence 1, Rhode Island.**

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# FRIDEN MODEL SRW —the most extraordinary automatic calculator you have ever seen

**STUDY THESE PICTURES:**

**1** Set number from which root is to be taken on Friden SRW keyboard

**2** Touch Square Root key corresponding to position of decimal point in the radicand

**3** See root appear in dials. This figure can be retained on keyboard if desired for further calculation. Need for copying root is eliminated

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**...appears automatically in the dials of Friden Model SRW when you touch one key**

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## WHAT'S NEW

### Computing Control— a Commercial Reality

***A new computing-control installation—delivered in January and on-stream since mid-March—gives all indications of meeting hoped-for economic and other gains in polymerization. More important, perhaps, is the experience and system-reliability information to be obtained.***

At the Texaco Port Arthur refinery, a Thompson-Ramo-Wooldridge Products RW-300 digital computer diligently controls a 1,800-bpd catalytic polymerization unit. Maintaining reactor bed temperatures between 470 and 490 deg F at 700-740 psi—a difficult feat in view of severe fluctuations in gas feedstreams—is one goal established by a joint study. The 318-page report showed profits could be improved, by staying within this temperature range, in two ways: theoretical operating efficiency could be upped from a usual maximum of 85-87 percent to a minimum of 93 percent; and catalyst replacement costs could be reduced by up to $75,000 a year.

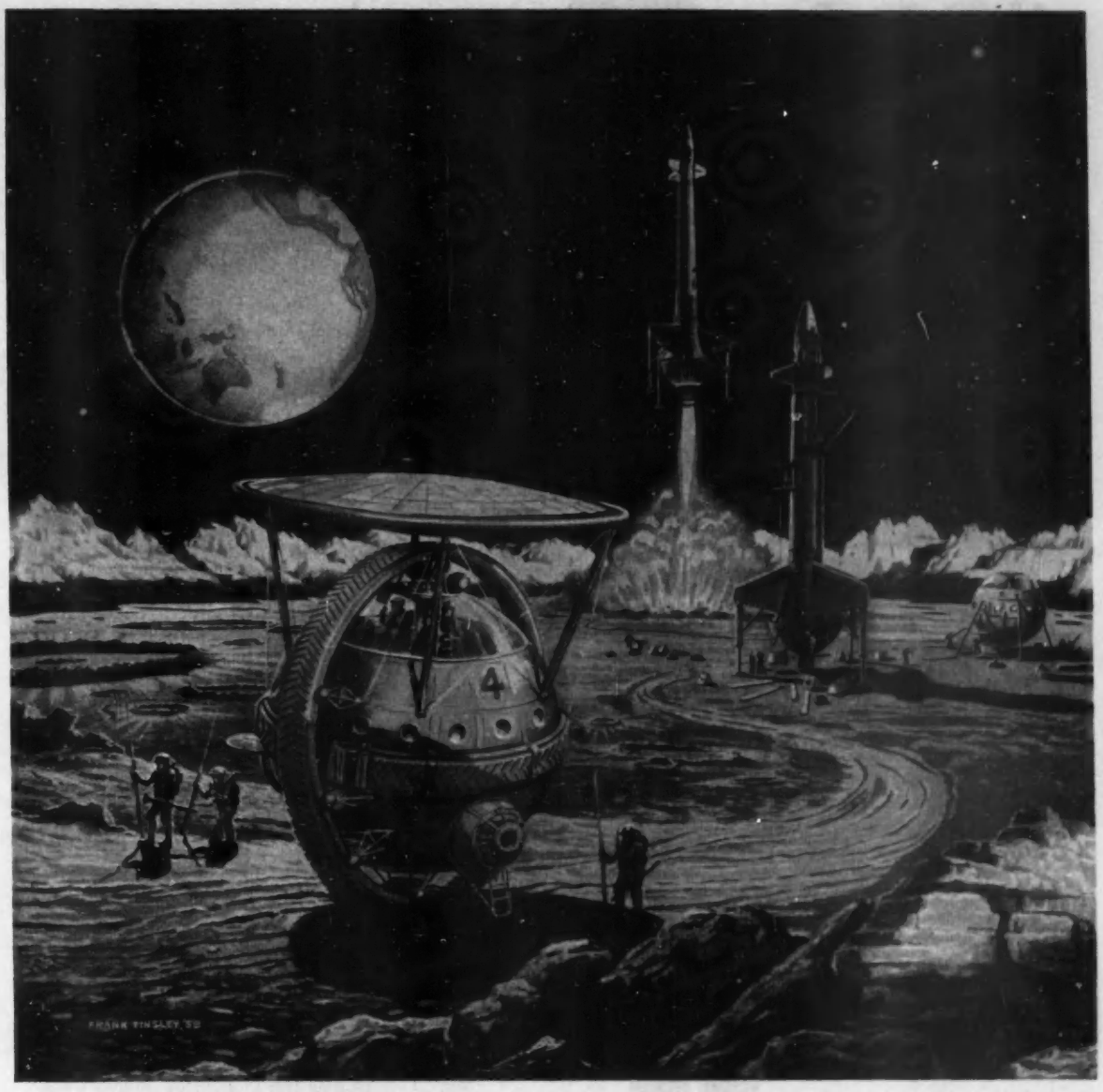
**The process**

Texaco chose the polymerization process for its first computing-control installation because it was small, fairly easy to analyze, not in-line with major refinery units, and due for modernization. The polymerization unit, which upgrades gases to high-octane gasoline, consists of 10 reactor pressure vessels or cases in parallel; each case has similar instrumentation and control systems.

The T-R-W computer calculates the best operating values for each vessel and for the total process, receives 103 measured variables and delivers 16 outputs. Seventy-two inputs are temperatures, 70 of them from catalyst beds. Three inputs are from Leeds & Northrup chromatographs, which measure the propylene content in significant streams. Pressure makes up two other inputs. Ten of 26 flow inputs are for feed to each vessel, one is for total feed, and 10 are for catalyst quench.

**The computing-control system**

Using these inputs, the computer performs its primary mission, calcu-



STEPS IN THE RACE TO OUTER SPACE

# *Lunar Unicycle*

This 30-foot high Unicycle is designed for preliminary exploration of the Moon, once a base camp has been established. It's entirely constructed of inflated, rubberized fabric, with the exception of strengthening members, hatches and a few other items of equipment. Gyros stabilize and steer the vehicle; electric motors furnish the driving power.

Electricity for the motors and instrumentation comes from solar batteries mounted in the "parasol". The cleated, rotating wheel upon which the Unicycle travels is made of inflated tubes. A spare wheel, carried around the body, acts as a bumper in traversing narrow defiles. Built in two sections, these wheels are assembled by belt-lacing type fasteners.

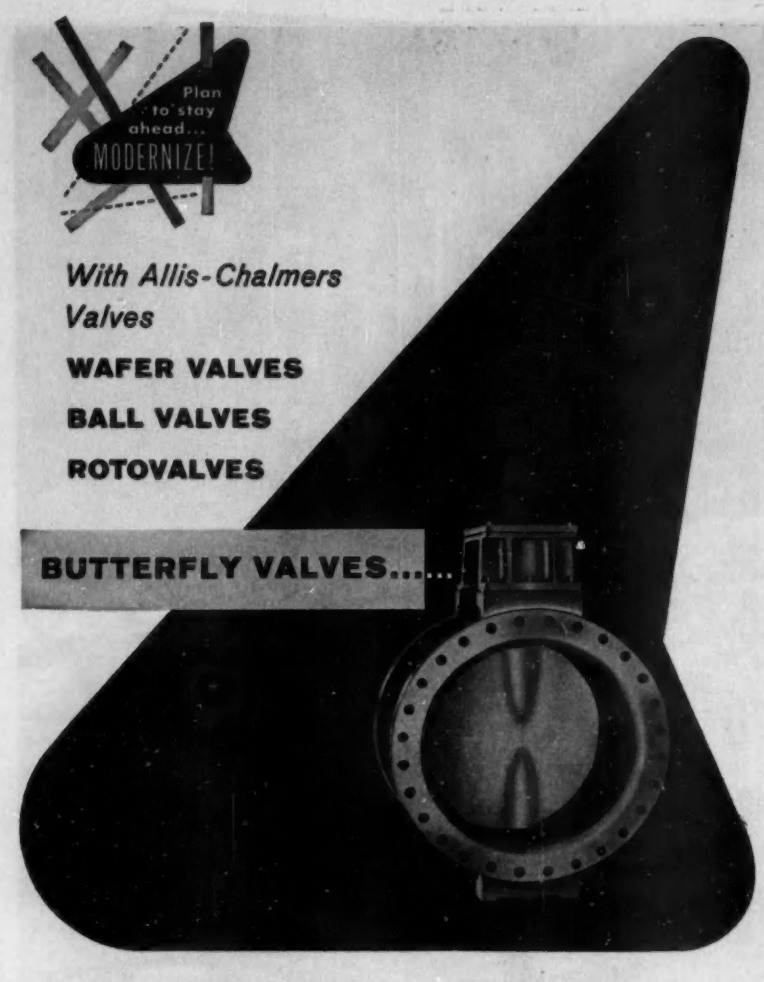
The upper level, the navigating and communications deck, is ringed with recording and surveying instruments. Living quarters make up a middle deck and below is the hold with supplies, spacesuits, oxygen equipment and spare apparatus, needed for survival.

In the background, two of the expedition's ferry ships are seen; one landing, one unloading in the bright Earthlight.

Inertial navigation systems will play an increasing role in the exploration of outer space. **ARMA** is actively supporting the Air Force's program in long range missiles and is in the vanguard of the race to outer space. **ARMA** . . . Garden City, New York. A Division of American Bosch Arma Corporation.

6110-A

**AMERICAN BOSCH ARMA CORPORATION**




To help solve your fluid and gas control problems, the broad line of Allis-Chalmers butterfly valves gives you:

***Uniform Control In All Positions*** — You get consistent flow control through all positions in the normal regulating range. The flow curve within the broad control range is a straight line semi-log characteristic. Cam driven positioners can furnish other characteristics.

***Fast Regulation and Closure*** — Speed of regulation and closing can be as fast as 1/10 second, or as long as system conditions require!

***Minimum Pressure Drop Saves Power***— In open position, the streamlined vane simulates Venturi action. Pressure drop is less than in many other valve types, helping to hold down your pumping costs.

***Compact, Light Weight*** — Compact design and light weight permit more concise, space-saving layouts, cut construction and in-place costs.

For further information on Rotovalves, and butterfly, wafer and ball valves, contact your nearest A-C valve representative, or write Allis-Chalmers, Hydraulic Division, York, Penna.

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*Hydraulic Division* HYDRODYNAMICS
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Rotovalves • Ball Valves • Butterfly Valves • Free-Discharge Valves
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**ALLIS-CHALMERS**

CIRCLE 33 ON READER-SERVICE CARD


## WHAT'S NEW

lating: one total feed-flow rate; 10 individual reactor-case feed-flow rates, each of which can be different, depening on catalyst activity in the particular bed; one reactor pressure; one recycle flow rate (recycle is not presently used); one water-injection flow rate; and two catalyst bed outlet temperatures, one for each group of five vessels.

The 16 computed outputs, converted to pneumatic form, are actually set-point signals for (modified) conventional three-action controllers (Bristol), which manipulate appropriate flow-control valves. Each computed cat-bed temperature sets 15 controllers to the same value.

To get the equations and coefficients for programming the computer, Texaco and TRW engineers combined past operating data (using regression analysis), experience of operating personnel, and classical analysis of process physics and chemistry. The program is stored in the "permanent" section of the 7,936-word drum memory, but up-dated information can be entered at the process engineer's discretion via edge-punched cards prepared on the system's Flexowriter.

Chromatograph calibration, initiated once a day by the computer, automatically analyzes a reference gas and stores the results in the computer memory. The computer also starts on-stream chromatograph analyses, comes back later to read propylene content, and interprets the analysis against latest stored calibration information.

Depending on the cycle, the computer can: perform control and analytical instrument functions, check instruments, scan a 55-variable alarm, and oversee a computer self-check, including check of analog inputs (5-min cycle); log 32 averaged and calculated values (60-min cycle); standardize chromatographs (8-hour cycle); print out averages and prediction of time for next catalyst change (24-hour cycle).

**How much?**

Costs for the Port Arthur installation are $98,000 for the computer and $36,000 for the analog-digital converter. The controllers, chromatographs, sensing elements, pneumatic-to-electric and electric-to-pneumatic transducers, and other instrumentation bring the total cost up to $300,000. No exact cost figures are available for system installation, or for the several man-years of application and project engineering.

—Harry R. Karp

**Standby time** is no problem with the new, cool (all-transistorized) Mincom C-100. No blowers necessary — and the new Mincom Model C-100 Instrumentation Recorder/Reproducer is particularly new in its simplicity and reliability. Six speeds record frequencies from 50 cps to 100 kc. Only 500 watts input for 14-track system. No mechanical brakes. Only 0.1% flutter and wow. Instant push-button speed control, no belt changes. Interested? Write Mincom for specifications today.

3M ... WHERE RESEARCH IS THE KEY TO TOMORROW

**MINCOM** DIVISION **MINNESOTA MINING AND MANUFACTURING COMPANY**

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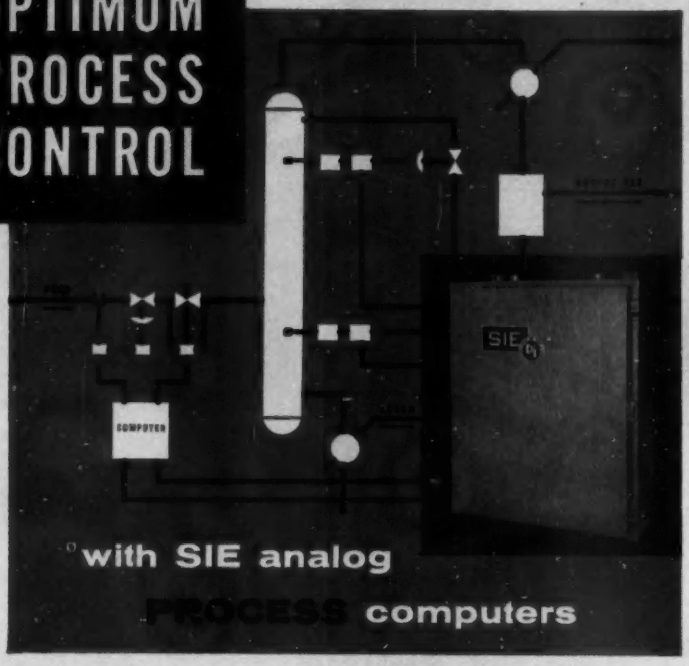
# OPTIMUM PROCESS CONTROL




with SIE analog PROCESS computers

**no ● moving parts**
**no ● vacuum tubes**
**no ● contacts**

**SIE CM-2 Analog Computers** provide precise control in chemical, petrochemical, refining, and similar process applications, to a degree never before possible. Using this new concept, process variables are taken into account in adjusting set-points automatically to achieve optimum output yield.

**Using Magnetic Amplifiers and Transistors** CM-2 Series Computers have a **trouble-free life expectancy in excess of 100,000 hours,** yet in a typical fractionator application now in operation, computer cost was less than $5000.

**Write For Brochure Describing Applications** in Feed-Ahead, Feed-Back, and Operator Guidance computations. SIE engineers will welcome the opportunity to discuss the use of CM computers in your specialized process control applications.

**SOUTHWESTERN INDUSTRIAL ELECTRONICS CO.**
**A Division of Dresser Industries, Inc.**
**2631 Post Oak Rd. • P. O. Box 13058 • Houston 19, Tex.**

SIE

**CIRCLE 35 ON READER-SERVICE CARD**


## WHAT'S NEW

### Computer Horizons . . .

**. . . are sighted at Western Joint Computer Conference. Some "blue sky" areas start computer men thinking seriously.**

SAN FRANCISCO—The future of computers and the speed with which computer technology is moving ahead kept almost 2,000 engineers intrigued at the Western Joint Computer Conference in March. The theme of the meeting—"New Horizons in Computer Technology"—gave speakers a platform for some unique presentations. Typical examples:

"Emergency Simulation of the President of the United States" by L. Sutro of Minneapolis-Honeywell's Datamatic Div. In this paper, Sutro expressed concern with the time the U. S.'s chief executive might require for decision-making in an emergency. He suggested that a computer work in parallel with the President over a period of time to develop a simulation of the President's duties. However, the speaker warned, a preset program could not take into account rapid changes and new events in the environment of government.

Machine learning concepts were explored by two good papers: one by H. Campaigne, American University; the other by P. H. Green, University of Chicago.

Real-time computer techniques for control were explored by W. J. Milan-Kamski of Epsco Corp. His paper, "A High-Accuracy, Real-Time Digital Computer", described an operational machine for navigation of a missile-launching submarine. The machine uses digital elements in an analog fashion for accuracy and speed.

#### Other developments

Interesting but more prosaic developments were also described. For example, R. I. Tanaker, Lockheed Aircraft Corp., covered the ACRE computer, a digital, stored-program machine developed for missile checkout. The session on components and circuits seemed to concentrate on magnetics, particularly on multi-aperture devices and twistors.

In a final session, devoted to a look at the future, Prof. Howard Aiken of Harvard claimed that the theoretical aspect of computer technology was the most fertile field for advances.

—E. M. Grabbe

*For a wide range of applications in—*

**Communications**

**Data Processing**

**Automation**

Model 28 RT Sets may be mounted in pairs in this newly designed Teletype Universal Cabinet, ideal for office or communications center installation.

# New Teletype Model 28 RT Set

The Teletype Model 28 Reperforator Transmitter-Distributor Set features *three* facilities in one unit. It combines: (1) a typing or non-typing TAPE PUNCH . . . with (2) a TAPE READER . . . plus (3) intermediate TAPE STORAGE facilities.

This new equipment will accept 30 or 60 ma signals at line speed, convert them into perforations in paper tape, and retransmit the data at the same or another speed.

Speeds from 60 to 200 WPM are available for 5-level code. A manual gearshift permits selection of 60, 75 or 100 WPM, on units with either typing or non-typing tape punches. Units with non-typing tape punches operate at 200 WPM with a fixed gear arrangement.

The Model 28 RT is adaptable to a wide range of applications. For example:

**Automatic Switching Systems.** For high-speed, cross-office transfer of data.

**Relaying.** Between carriers or circuits.

**Data Processing.** Between terminal communications facilities and business machines.

If you would like more information about this new and versatile Teletype unit, please write for descriptive literature to: Teletype Corporation, Dept. 22E, 4100 Fullerton Ave., Chicago 39, Illinois.

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SUBSIDIARY OF *Western Electric Company*, INC.

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# BALLANTINE VOLTMETER

**Model 300-D** **Price: $235.**

gives you utmost Accuracy, Stability and Reliability ... plus these features

- **Long life**
- **High input impedance**
- **Wide voltage range**
- **Large easy to read meter with overlap**
- **High accuracy at any point on the scale**
- **Light, compact, rugged**

**SPECIFICATIONS**

**VOLTAGE RANGE:** 1 millivolt to 1000 volts rms. in 6 decade ranges (.01, .1, 1, 10, 100 and 1000 volts full scale).

**FREQUENCY RANGE:** 10 to 250,000 cps.

**ACCURACY:** 2% throughout voltage and frequency ranges and *at all points on the meter scale.*

**INPUT IMPEDANCE:** 2 megohms shunted by 15 $\mu\mu f$ except 25 $\mu\mu f$ on lowest range.

**DECIBEL RANGE:** −60 to +60 decibels referred to 1 volt.

**STABILITY:** Less than ½% change with power supply voltage variation from 105 to 125 volts.

**SCALES:** Logarithmic voltage scale reading from 1 to 10 with 10% overlap at both ends; auxiliary linear scale in decibels from 0 to 20.

**AMPLIFIER CHARACTERISTICS:** Maximum voltage gain of 60 DB; maximum output 10 volts; output impedance is 300 ohms. Frequency response flat within 1 DB from 10 to 250,000 cps.

**POWER SUPPLY:** 115/230 volts, 50-420 cps, 35 watts approx.

*Write for catalog for complete information.*

**BALLANTINE LABORATORIES, INC.**
**Boonton, New Jersey**

**CIRCLE 37 ON READER-SERVICE CARD**


## WHAT'S NEW

### AACC Reports:

- *Pooled U.S. control meetings start in the fall.*
- *General Assembly of IFAC gathers in Chicago this year.*
- *U.S. participation in the Moscow 1960 control conference firms up.*

Redundant technical meetings, a frequent nuisance for the control engineer, may be on the wane. Beginning in the fall of this year, five societies (ASME, IRE, AIEE, ISA, and AIChE) will pool their annual efforts and hold one joint conference on control theory. The combined meeting will be held under the auspices of the American Automatic Control Conference (AACC), according to Purdue University's Rufus Oldenburger, president of AACC.

In the past, ASME, IRE, AIEE, ISA and AIChE have all held special control theory conferences or major sessions at other than their annual meetings. Each has always invited the other societies, but the result was still three or four special conferences on nearly identical subjects.

Sponsorship of the annual joint meeting will rotate among the five societies, which have affiliated with AACC, according to this schedule:

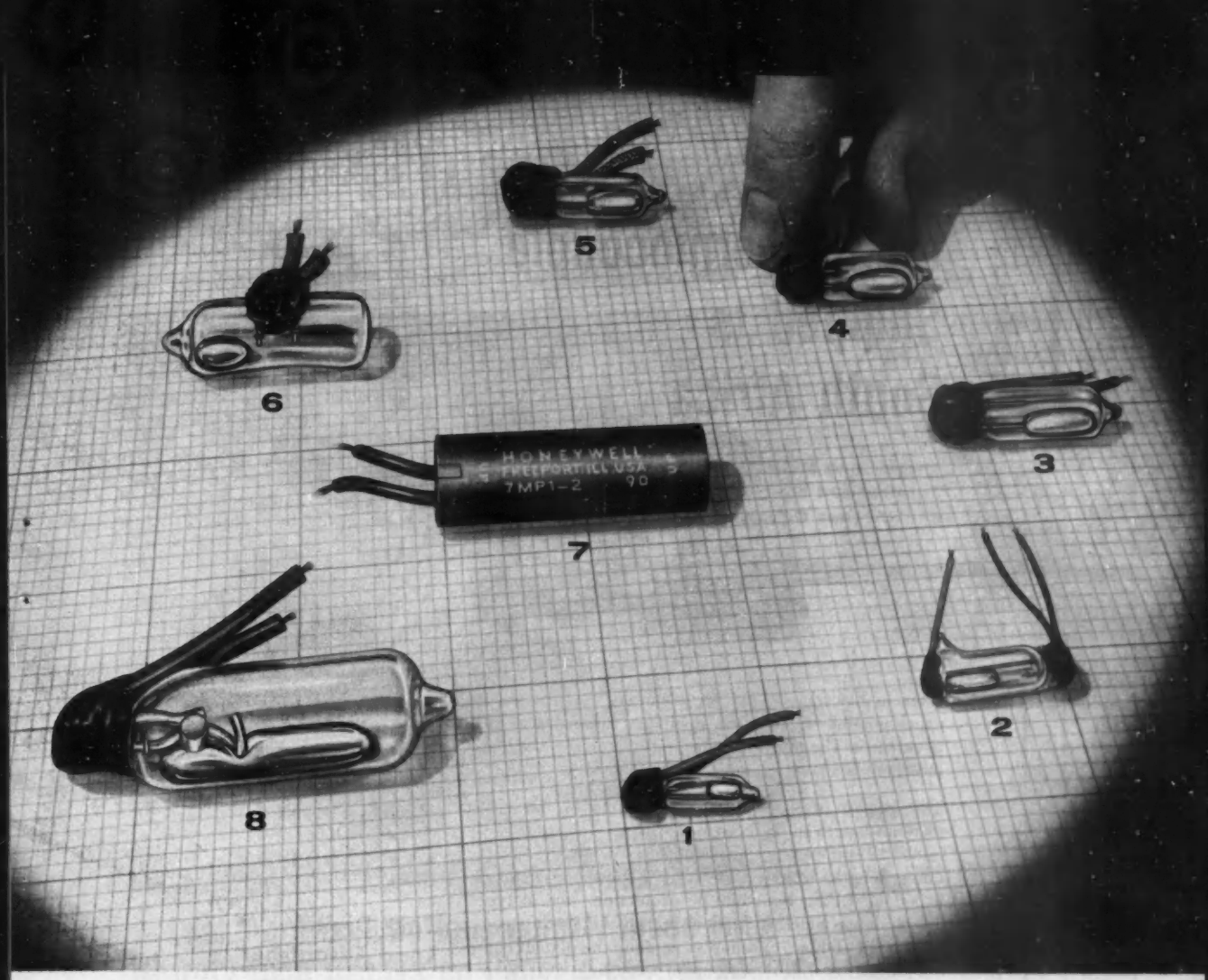
| | |
|---|---|
| IRE | 1959 |
| ASME | 1960 |
| ISA | 1961 |
| AIEE | 1962 |
| AIChE | 1963 |

Chairman of the joint-society meeting steering committee is N. B. Nichols, chief engineer of Taylor Instrument Cos.

• **International activities** – AACC's early efforts, reported President Oldenburger, have been devoted to representing its affiliated societies in international activities in automatic control, principally in the activities of IFAC (International Federation on Automatic Control). AACC will play host to the 1959 General Assembly meeting of IFAC in Chicago the week before the ISA annual meeting.

At this business session, IFAC's governing body will set policy for the technical subcommittees in the group. Possible areas: standardization, nomenclature, literature abstracting.

The assembly will be held at Northwestern University. Chairman of the AACC host committee: D. N. Boyd, Universal Oil Products. Arranging facilities are A. Sperry, Panellit; D.




# 8 widely useful mercury switches now in automatic production

**1** AS419A1—Length: 0.90″. Combines smallest available size with long life and reliability. Weight: 0.9 gram (without leads). Tube diameter: 0.174 nominal. SPST.

**2** AS603A1—Length: 1.060″. Ultra small, super-sensitive, sealed. The most precise mercury switch available. Weight: 3.5 grams (including leads). SPDT.

**3** AS417B2—Length: 1.500″. Offers small size with 3 amps. capacity at 115 vac or vdc.

**4** AS408C1—Length: 1.375″. Nominal rating of .25 amp. at 1.5 vac or vdc, also operates in micro-volt and milli-ampere ranges.

**5** AS408D1—Length: 1.375″. An economical switch widely used in appliances and vending machines. SPST. Rating: 1 amp., 115 vac or vdc, resistive.

**6** AS702B1—Length: 1.625″. Mercury pulse switch has curved glass tube. Used in business machines, counters, timers, etc. SPST.

**7** 7MP1-2—Length: 1.875″. Embedded in synthetic rubber and enclosed in a nylon can. Resists shock, corrosive fumes, and fungus. Unaffected by oil and water. Operates in temperatures from −35° to +200°F. 3 amps., 115 vac or vdc, resistive. SPST.

**8** AS454A34—Length: 2.500″. Medium size. Handles loads up to 10 amps., 115 vac, resistive. Sealed contacts. Low force tilt action. Wide use—machines, tools, appliances, etc.

Each of these Honeywell Mercury Switches is exceptional in terms of its own qualities and characteristics. Just as important, *all* are in fully automatic production at MICRO SWITCH in Freeport.

This means that one of a kind is precisely like another of its kind—same weight, same mass, same external dimensions within a thousandth of an inch. *This* means —as you know—uniformity of performance and uniformity of fit that make life easier for designer and production man. And the savings from automatic production permit minimum price for highest quality.

Hundreds of Honeywell mercury switches are offered by MICRO SWITCH. Personalized application engineering service is available from branch offices in principal cities. Put this combination of quality, broad line, and service to work for you. Send for Catalog 90.

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**MICRO SWITCH Precision Switches**

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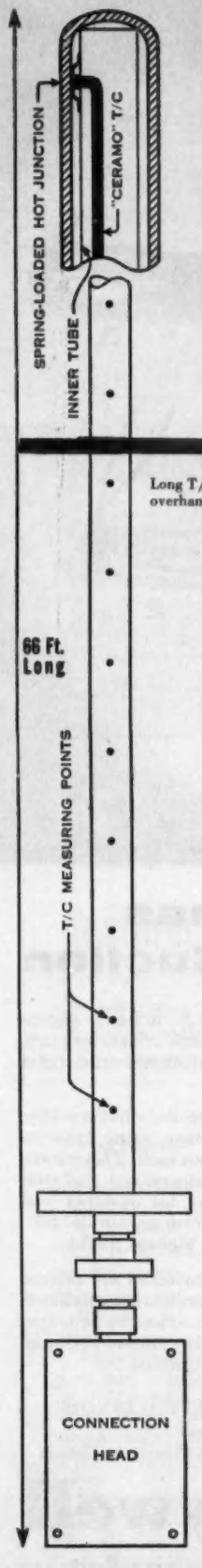
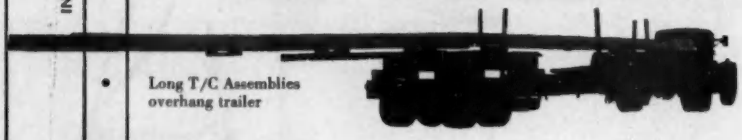



# 66 Ft. Multi-Thermocouple Shipped to South Africa

**Three Long Multi-Thermocouples, Totaling 194 Feet Sent Across Ocean By Thermo Electric**



Long T/C Assemblies overhang trailer

Thermo Electric makes thermocouples for just about every possible application—including some pretty unusual ones. The multi-thermocouple assembly diagrammed here is a good example. It's 66 feet long.

The longest of three, this assembly has a total immersion length of 63'7". The entire unit actually contains 12 different thermocouples—in progressively longer lengths from 9'1" to 63'7". These are enclosed in a 1½" I.P.S., Schedule 80 protection tube of type 304 Stainless Steel. Individual thermocouple construction is of T-E's "Ceramo"—ceramic insulated conductors encased in overall metal sheathing. O.D.'s are ⅛" with 22 gage Iron-Constantan conductors. Hot junctions are welded closed and, for fast response, are spring-loaded against the inner wall of the protection tube.

The three assemblies were sent by T-E to Durban, South Africa for installation in a catalyst reactor. They are typical of what Thermo Electric is currently doing in the field of temperature measurement. T-E equipment is being used all over the world for important temperature measuring jobs. Assemblies like this, used in deep vessels, will measure temperatures at any desired level. Thermo Electric also makes miniature thermocouples as small as ½" immersion length. Whatever your needs, for large or small thermocouples, for low or extremely high temperatures, for any type of application, contact Thermo Electric. Our extensive research, engineering and manufacturing facilities are at your disposal.

***Write For Detailed Information***

**Thermo Electric** CO., INC.
SADDLE BROOK, NEW JERSEY

In Canada: THERMO ELECTRIC (Canada) LTD., Brampton, Ont.

CIRCLE 39 ON READER-SERVICE CARD


## WHAT'S NEW

Bergman, Universal Oil Products; and R. Jones, Electrical Engineering Dept., Northwestern University.

• **Moscow meeting**—The big international highlight in automatic control in 1960 will be the first IFAC Congress, scheduled for Moscow. AACC's Review Committee has already started gathering U. S. technical papers. The committee: E. M. Grabbe (Thompson Ramo Wooldridge Inc.), chairman; J. Truxall (Polytechnic Institute of Brooklyn), chairman, Theory Subcommittee; N. B. Nichols, chairman of Instrumentation & Components Subcommittee; and D. M. Boyd, chairman, Applications Subcommittee.

According to the Review Committee, the number of U. S. papers will be restricted to the 60 best submitted. The congress will probably hear a total of 200 papers.

Societies affiliated with AACC are expected to reprint the U. S. papers chosen for presentation. J. R. Ragazzini, NYU's dean of engineering, will edit the English proceedings of the congress. Probably consisting of three volumes, the proceedings will be available in 1961, will cost somewhere between $25 and $50 a set.

### First Digital Load Dispatcher

Philadelphia Electric Co. will install a digital-computer-controlled system for economic dispatching of utility generating stations. Scheduled for on-line operation by the end of 1960, the Minneapolis-Honeywell system will be the first to use digital techniques and equipment. All previous automatic load dispatchers have been analog computers.

The system will have three main functions: 1) to calculate the least expensive pattern of allocating generation to meet the system demands; 2) to assign automatically this allocation to generating units; and 3) to obtain cost data for billing power exchanged with neighboring electric companies.

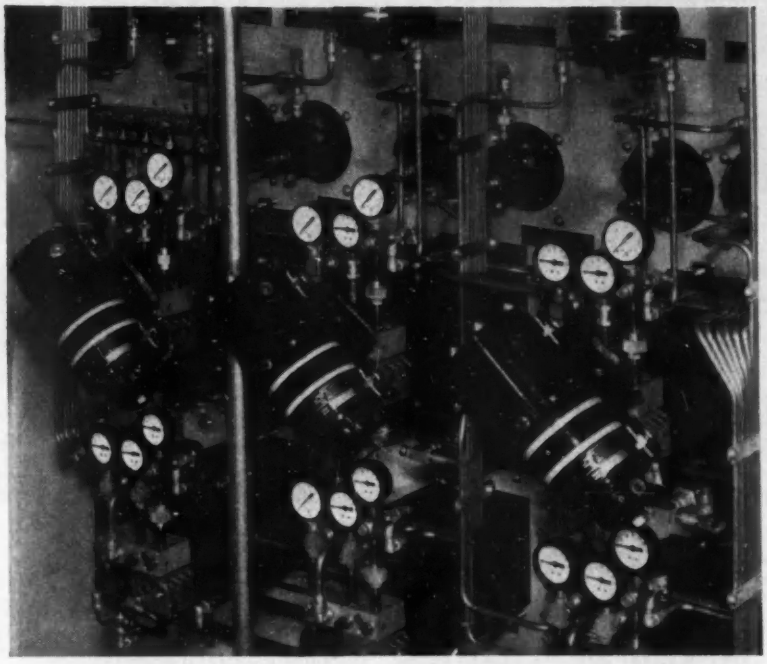
Heart of the system will be a transistorized, high-speed computer, the D-290, developed by Honeywell's Datamatic Div.

•

Inexpensive radiation warning device for the home has been developed by Tracerlab, Inc. Called the Banshee, the unit plugs into a standard radio or television set, sounds a wailing alarm through the loudspeaker when exposed to radioactive fallout in dangerous concentrations.

# IMPERIAL Engineering and Data File

ENGINEERED TUBE FITTINGS — VALVES — TUBING TOOLS



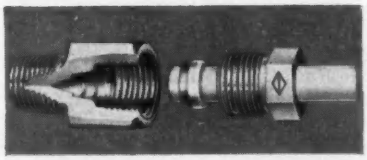
## Leakproof connections quickly made with Hi-Duty tube fittings on Panellit control boards

Tube fittings that assemble to tubing fast and provide assurance against leaks are one of the top requirements for control boards.

That's why Panellit selected Imperial Hi-Duty fittings on this panel board used for automatically controling a variety of oil refinery processes.

Hi-Duty Fittings have a one-piece nut and sleeve. A joint is made simply by pushing tube into fitting and tightening nut. Sleeve shears off and becomes permanently attached to tube. One man can easily assemble up to four Hi-Duty fittings in the time it takes to assemble one flare fitting. Hi-Duty assembles one-third faster than compression fittings and can be disconnected and reconnected repeatedly without leakage. And they withstand five times as much vibration as compression or flare fittings.

**Write for Bulletin No. 3002**



Disassembled Hi-Duty Fitting shows how sleeve has become permanently attached to tube.

### HOW HI-DUTY SAVES 36% TO 72% ON INSTALLATION TIME!

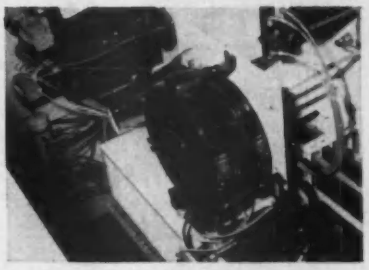
| TYPE OF FITTING | AVERAGE TIME FOR EACH JOINT | JOINTS PER HOUR |
|---|---|---|
| HI-DUTY | 11.7 sec. | 307 |
| Regular compression | 18.5 sec. | 194 |
| Flare | 48.2 sec. | 74 |

*These studies were made under actual shop conditions.*

IMPERIAL

THE IMPERIAL BRASS MFG. CO.
6300 W. Howard St., Chicago 48, Illinois
In Canada: 18 Hook Ave., Toronto, Ontario

## Poly-Flo fittings on color-coded tubing simplify servicing



International Paper Company service engineers enjoy simplified checking of 14-foot graphic control panels containing automatic and manual controls for operation of a complete pulp bleaching plant.

Polyethylene instrument loops are color-coded according to products. Nine tubing colors are available conforming to I.S.A. standards. Tube connections are made with Imperial Poly-Flo fittings.

In the event servicing is necessary, the engineer speedily disconnects and reconnects Poly-Flo fittings. No wrench needed . . . fittings need only to be finger tightened and joints stay tight.

**Write for Bulletin No. 3025**

## Free handbook tells how to work with tubing

This practical book tells you how to cut, flare, bend, swage, ream and solder tubing . . . fully describes modern tube-working practice.

**Handbook No. 369**

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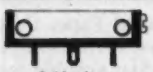
# TRIMPOT®

**subminiature potentiometers in hundreds of variations available from stock!**

*military and commercial units*

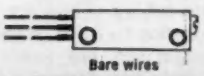
**WITH THESE TERMINALS**

Insulated stranded leads



Solder lugs

Printed circuit pins



Bare wires

**IN THESE TYPES**

| | |
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| High temperature | High resistance |
| Humidity-proof | Panel mounted |
| Dual output | Subminiature size |

plus many others

**WITH THESE RESISTANCE ELEMENTS**

Wirewound — Resiston* Carbon

This is the world's largest selection of leadscrew actuated potentiometers — 500,000 available from leading electronics distributors across the nation. Trimpot offers reliable performance . . . multi-turn adjustment for precision settings . . . self-locking shaft for stability. They're so small 12 to 17 units can be mounted in a square inch of panel space! Specify Trimpot . . . manufactured only by Bourns. Write for new brochure and list of distributors.

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**Exclusive manufacturers of TRIMPOT® & TRIMIT®. Pioneers in potentiometer transducers for position, pressure and acceleration.**

**CIRCLE 41 ON READER-SERVICE CARD**




## AROUND THE BUSINESS LOOP

### Marketing Techniques . . .

**. . . are getting more of the spotlight as competition mounts in the control field. GE and Beckman have developed interesting approaches.**

The Value Line Investment Survey was reported last month as saying that a rise in demand is in store for machinery (CtE, April, p. 66). This is all very well, as far as it goes; but the survey also noted the development of several new, postwar wrinkles in the road to higher sales, which could make things rough in the European markets for American manufacturers of machine tools.

The survey went so far as to consider as being permanently lost the bulk of the American export market for machine tools, particularly hand tools, drills, and lathes; though it did add that imports from foreign makers do not seem to be making more than scattered inroads in this country. This kind of report provokes a lot of thinking, and it is hard to imagine a control engineer reading it and not stopping to wonder about the status of marketing techniques being used by his company, whether or not it is a machine-tool builder and whether or not it has overseas markets.

• **Two approaches**—All of which brings up the fact that two companies in the field, General Electric and Beckman Instruments, are making, or see the need to make, unique advancements in their marketing establishments. Here are brief descriptions of what they are doing.

GE's concern is with its domestic markets. From a product-oriented organization, with sales components selling one product line to all markets, GE's Instrument Dept. has become market-oriented: now it sells several selected product lines to specific markets, and the results are more efficient customer service, better integration with the sales force, and the promise of a smoother transition to a larger operation when the time comes.

At the core of the new organization are two sales subsections, whose areas are industrial and electric instrument sales, and instrumentation equipment sales and product planning. Each is responsible for serving specific industries and markets with associated Instrument Dept. products. For example, one unit within one of the subsections handles products going to a wide range of instrument distributors; another all products purchased by original equipment manufacturers; and still another, all instruments sold to electric utility and industrial users.

• **Has already scored** – Market-oriented selling is already working well for the department's aircraft instruments, managed by Harold E. Brown. His Aircraft Instrument Product Section has been integrating engineering, manufacturing, and marketing for airborne equipment since late 1958.

Instrument Dept. General Manager E. E. Parker describes the new concept in three telling phrases: "extremely concentrated, rifleshot market coverage, and better sales and management teamwork".

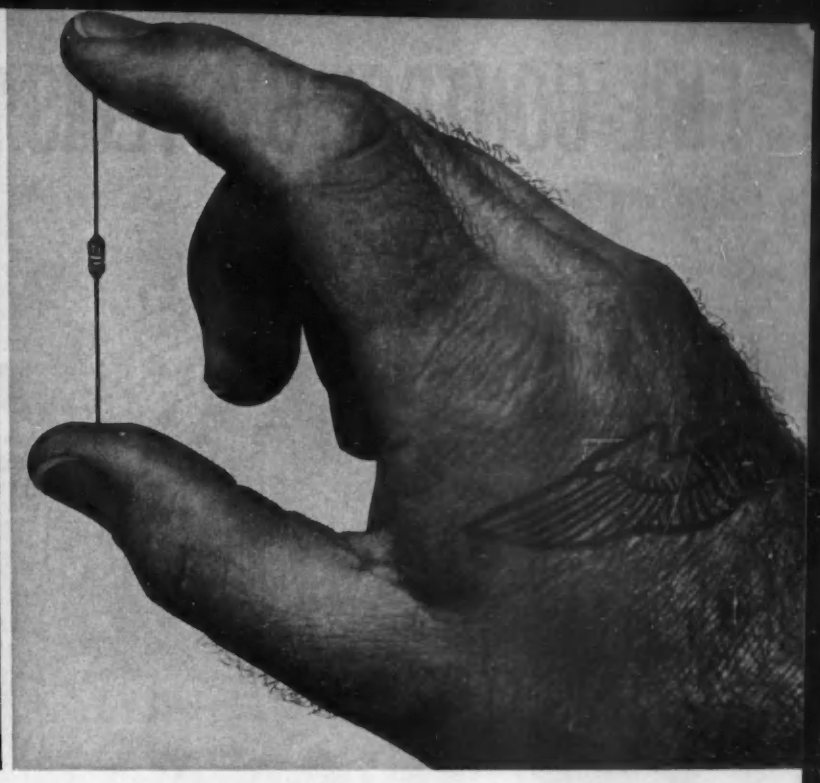
Overseeing the electric and industrial instruments sales subsection, and thus the marketing of the bulk of the Instrument Dept.'s industrial products, is Manager J. E. McQuillan. H. S. Day, manager of instrument equipment sales and product planning, has responsibility for some highly-specialized areas, including nuclear reactor instrumentation, utility instrumentation systems, and industrial process instruments.

Other GE appointments made in line with the reorganization involve M. H. Bensky, named manager of marketing instrumentation; E. R. Harrison, manager of product planning; H. E. Shattuck, manager of product service; and R. L. Moeller, specialist in personnel and special assignments. In their hands is responsibility for more than 300 different types of precision measuring devices intended for virtually every customer group.

• **Competition abroad**—Beckman, on the other hand, is concerned with developments in the European market. But because it believes it has taken, and is still taking, the only measures that can stave off this market's extinction for American companies, its concern is not so much with itself as with those companies that have not as yet established operations abroad. These operations, Beckman believes, are the only answer to mounting competition from foreign firms doing business within sanctioned economic unions.

Speaking to a meeting of the For-

# NOW — SPECIFY TI GLASS DIODES MEETING AIR FORCE SPECS!



## Guarantee 400 ma DC at 1 v

TI AF1N645, AF1N647, AF1N648 and AF1N649 diffused-silicon glass diodes now meet MIL-E-1/1143 . . . giving you 400 ma DC at 1 v . . . 225 to 600 v PIV . . . operation from —65 to 150°C and 600 mw dissipation. The inherently low junction temperature of these TI glass diodes provides a new high in reliability by combining the lowest forward-voltage drop with high power dissipation package.

In commercial production for more than two years, the 1N645 series is available in *production quantities* to meet *all* your requirements.

Simplify your procurement and stocking problems by standardizing on the TI 1N645 series . . . truly general-purpose high-reliability diodes. Contact your nearest TI Sales Office for fast delivery of production quantities.

| maximum ratings | AF1N645 | AF1N647 | AF1N648 | AF1N649 |
|---|---|---|---|---|
| specifications | AF1N645 | AF1N647 | AF1N648 | AF1N649 |

from THE WORLD'S LARGEST SEMICONDUCTOR PLANT

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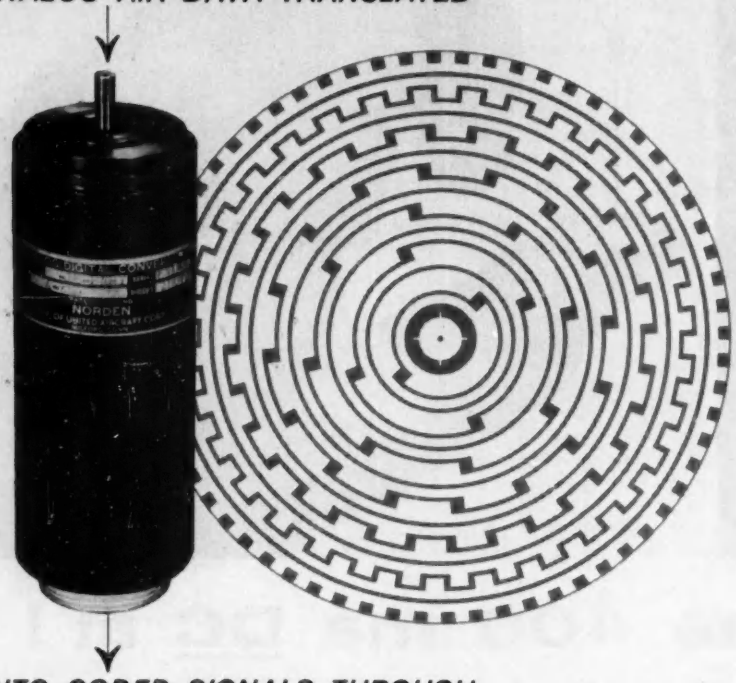
DALLAS, TEXAS

# FIRE CONTROL SYSTEMS?

*ANALOG AIR DATA TRANSLATED*




*INTO CODED SIGNALS THROUGH*

# NORDEN DIGITAL CONVERTERS

The vital link between air data computers and fire control computers in a number of today's high performance weapons systems is a Norden digital converter . . . the Self-Selecting V-Brush Shaft Position Encoder.

This small, rugged precision instrument, one of many Norden converters, changes analog flight data into the pure binary electrical representations needed in fire control computation. It offers automatic error-monitoring, coupled with the completely unambiguous parallel output produced through Norden's unique code disc without extensive external brush selection logic. The result is highest accuracy and reliability. Accuracy in the model shown above is 1 part in 524,288.

Other features are smallest size, (standard BuOrd size 18 synchro mount), longer life (4,000,000 revolutions at 200 RPM), and wide versatility, all backed by Norden's engineering excellence and modern production facilities. Call TRinity 4-6721, or write for complete technical data or engineering consultation on this or any other converter applications.

**NORDEN** Division of United Aircraft Corporation

Milford Department, Wiley Street, Milford, Connecticut

**CIRCLE 43 ON READER-SERVICE CARD**




## WHAT'S NEW

eign Trade Association in Los Angeles, Calif., Beckman's E. H. Cherniss, director of foreign operations, sketched two of these economic unions, said they will try to parlay high external tariffs, low wage rates, market proximity, and other economic advantages into a protective screen against competitive imports from the U. S. and other countries. One of these unions, said Cherniss, is the Common Market, consisting of Germany, Italy, France, The Netherlands, Belgium, and Luxembourg. The other, the Free Trade Area proposed by Great Britain, covers 11 other nations, from Scandinavia to the Mediterranean.

"It is absolutely necessary," the

## COMPANY STATEMENTS[1]

| Company | $ | % |
|---|---|---|
| American | 4,777,738 | (−48.0) |
| Brake Shoe[2] | 137,998,280 | (−26.0) |
| American Machine | 11,008,000 | (− 7.0) |
| & Foundry[2] | 230,877,000[3] | (−12.0) |
| Amphenol-Borg[2] | 2,320,946[4] | (−30.2) |
| | 46,306,741[4] | (−13.8) |
| Borg-Warner[2] | 21,135,260 | (−37.9) |
| | 533,033,188 | (−12.4) |
| Chance Vought[2] | 8,957,626 | (+40.0) |
| | 333,192,432 | (+40.0) |
| Controls Co. | 1,309,263 | (+16.9) |
| of America[2] | 33,078,263 | (+22.0) |
| Electronics Corp. | 208,001 | (+13.9) |
| of America[2] | 6,639,121 | (−17.0) |
| Erie Resistor[2] | 510,441 | (− 6.0) |
| | 21,202,186 | (−14.3) |
| General | 304,267 | (−92.9)[5] |
| Precision[2] | 168,333,316 | (−9.05) |
| General | 553,647 | (+21.08) |
| Transistor[2] | 5,484,407 | (+61.8) |
| Hoffman[2] | 1,712,509 | (+ 3.4) |
| | 39,544,064 | (− 3.6) |
| Lear[2] | 1,607,751 | (+87.2) |
| | 63,627,475 | (− 1.6) |
| Magnetic | 142,483 | (+51.0) |
| Amplifiers[2] | 2,301,800 | (+28.0) |
| Philips | 1,175,892 | (+212.1)[6] |
| Electronics[2] | 14,832,677 | (+84.0)[6] |
| Servomechanisms[2, 7] | 17,300,000 | (−26.7) |
| Standard Coil[2] | 1,343,887 | (+63.3) |
| | 69,489,636 | (+13.3) |
| Tracerlab[2, 8] | 10,300,000 | (−14.2) |

[1]First figure is net earnings, second is net sales; percentages reflect increases or decreases with respect to preceding fiscal year. [2]Fiscal year ending Dec. 31, 1958. [3]Includes rentals. [4]On a pro forma basis, following merger in December of Amphenol Electronics Corp. and The George W. Borg Corp. [5]Comparable 1957 figure: $4,263,949. [6]Reflects results of first full fiscal year under a new policy, emphasizing activities in the electrical, electronic, and chemical fields. [7]Net income negative by $48,000. [8]Net income negative, but 1957 loss reduced by 80 percent (from $1,400,000 to $258,000).

# Transistorized NLS M-24 Selected for Missile Checkout System

Analog to digital conversion in Nortronics' Universal Datico is accomplished by the ultra-reliable NLS M-24, the transistorized Digital Volt-Ohmmeter that automatically and accurately measures and displays AC and DC voltages, voltage ratio and resistance.

In Datico, program control is performed by a punched paper tape. Test stimuli are automatically controlled by Datico and output signals (voltage, voltage ratio, and resistance) from the system under test are automatically selected and fed to the NLS M-24. The M-24 digitizes the system outputs to 0.01%, and provides numerical data to the indicator and control chassis for distribution to the data recorder, digital comparator, and visual display on a special NLS in-line readout.

The tape also establishes the go-no-go limits for comparison with the M-24's digital output. It then directs the system to the next channel to be measured.

Operation of the NLS M-24 in this system is completely automatic . . . the instrument is remotely operable, does not require zero setting, and is extremely stable over very long time periods. Over-all system speed is not compromised by analog to digital conversion time, the M-24 making each measurement in just 330 milliseconds.

The NLS M-24 meets the unusually great reliability demanded of automatic test equipment for modern electronic weapons systems. This reliability is assured by transistors, mercury-wetted contact relays (rated at 10 billion measurements), advanced circuit design, and thorough production and field testing.

Proved in the field in a variety of applications, the NLS M-24 Digital Volt-Ohmmeter is in production and ready to go to work for you. Write today for detailed information concerning this outstanding example of NLS leadership in the development and manufacture of digital instruments. A complete catalog of NLS instruments will be sent upon request.

*Originators of the Digital Voltmeter*

**non-linear systems, inc.** DEL MAR (San Diego), CALIFORNIA

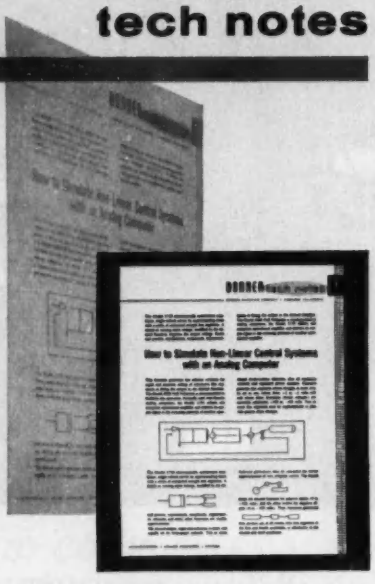
NLS—The Digital Voltmeter That Works...And Works...And Works!

*Announcing*

# DONNER computer tech notes

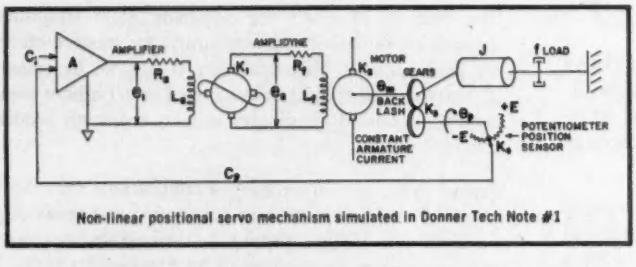
*News about*

- *Computer applications
- *New methods of simulation
- *Application of new feedback design techniques
- *Analog control systems



***Your free copy of Donner Tech Note #1 is ready now.***

Lead article in the first issue is titled "How to simulate a non-linear control system with an analog computer." A step by step analysis takes you through the intricacies of setting up a Donner analog computer to simulate a non-linear positional servo mechanism.




Non-linear positional servo mechanism simulated in Donner Tech Note #1

By simulating the system on the computer, the designer can examine system performance under the influence of every parameter. Changing constants and observing changes in response gives the designer a feel for the system impossible with a strict analytical approach.

*Donner Tech Note #1 contains complete photos and diagrams showing the solution to this problem. For your copy, call your nearby Donner engineering representative or write Dept. 085.*

ELECTRONIC ENGINEERS, exciting opportunity exists at Donner. Write today for full details.

**DONNER SCIENTIFIC COMPANY**
CONCORD, CALIFORNIA
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**CIRCLE 45 ON READER-SERVICE CARD**


## WHAT'S NEW

Beckman executive said, "that U. S. companies which intend to maintain and expand their business in the foreign markets begin manufacturing their products in the Common Market and/or the Free Trade Area. Unless they do, they are going to find themselves gradually shut out of Europe as well as other markets around the world."

• **Manufacturing cheaper** – About comparative manufacturing costs, Cherniss said: "In our German plant, the cost of making certain complex instruments is 22½ percent less than in the U. S. In Scotland, we found the manufacturing cost of a new item for that plant to be 26 percent less than in the U. S., where the item has been in quantity production for three years." The plants he named are in Munich and Glenrothes.

But there is more to establishing markets in Europe than simply overcoming an economic challenge, said Cherniss; there are some splendid opportunities, too, and they should be reason enough for putting up new plants: "In these two trade areas, the European market would consist of 224 million people and a gross product of some $220 billion. This can mean substantial opportunities for U. S. companies willing to become a part of this great new mass market."

### Spectroscopic Federation Yields to Society for Spectroscopy

In an attempt to bring more effective help to its 1,700 members, the Federation of Spectroscopic Societies has reconsolidated into the Society for Applied Spectroscopy. The new body, explained President William J. Poehlman of the A. O. Smith Corp., is a society of individuals, not, as the old federation was, a "society of societies".

The 18 groups that were members of the federation are now local chapters or sections in the new society. They are located in Milwaukee, Baltimore, Washington, Chicago, Cleveland, Detroit, Indiana, Los Angeles, Boston, New York, Buffalo, Dayton, Cincinnati, Philadelphia, Pittsburgh, Denver, San Diego, San Francisco, and sections of the southeastern U. S.

The New York society's publication, "Applied Spectroscopy", has been established as the official national magazine, and will go to all members. The multiplicity of annual meetings will be replaced by two a year. SAS hopes for a membership of 2,000.


**CIRCLE 46 ON READER-SERVICE CARD→**

*Now, from the Laboratories of CLARE,*

# THE MOST EXCITING RELAY DESIGN OF THE YEAR

## NEW *SIX-IN-LINE* HG6F RELAY BRINGS BIG SAVINGS IN SPACE, POWER, AND COST

Latest in the Clare line of Mercury-wetted Contact Relays, world famous for their billions of operations*, is Type HG6F, a six-in-line flat-pack relay. This striking new design provides the most reliable, durable, maintenance-free relays ever made anywhere, *plus these savings.*

### SAVES SPACE—

Unique packaging affords up to 50% savings in space over cylindrical multi-element mercury-wetted contact relays.

### SAVES POWER—

Six switches per coil saves operating power.

### SAVES COST—

Switch cost as much as 26% below cost of same number of switches in cylindrical packages.

*Mercury-wetted contact relays on test have completed over 8 billion operations with a contact-load of 250 volt-amperes, and are still going strong.

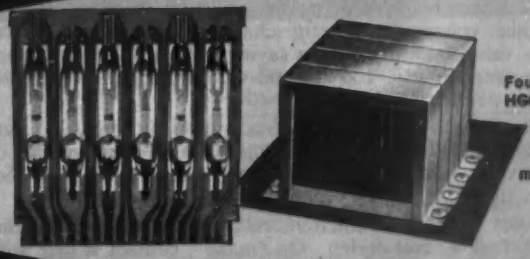
Compact CLARE TYPE HG6F Relay ready for mounting. Overall dimensions: 3.640" x 3.125" x 1.046"

### MECHANICAL FEATURES

- Flat, rectangular package makes most efficient use of chassis space.
- Printed circuit mounting eliminates customary internal wiring except for coil leads.
- Units can be stacked in line without interaction.
- No shelf deterioration; requires no maintenance.
- Contacts cannot wear, get dirty, stick by locking or welding, nor chatter.
- Tamper proof.
- Completely protected against dust and dirt, corrosive fumes, and explosive atmospheres.
- No mechanical damage when subjected to usual military shock and vibration tests.

### ELECTRICAL FEATURES

- Life expectancy measured in billions of operations.
- No contact chatter or bounce.
- Low and consistent contact resistance.
- Full line of coil resistances.
- Contacts rated at 5 amperes, 500 volts (d-c or rms)
  - Product of voltage prior to closing and current prior to opening, 250 volt-amperes maximum.
- Nominal operating time: 1 watt input, 11 milliseconds; 2 watts input, 7 milliseconds; 4 watts input, 5 milliseconds.
- Release time: 4 milliseconds or less. Maximum continuous dissipation: 5 watts at 100° F.



Arrangement of six-in-line mercury-wetted contact switches on printed circuit panel.

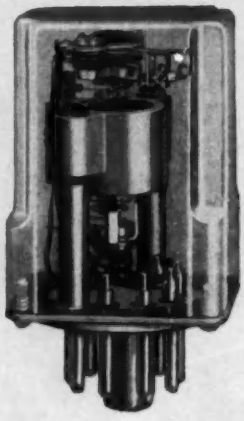
Four CLARE Type HG6F relays mount in a space 50% less than cylindrical multi-element assemblies.

**SEND FOR BROCHURE CPC-2**

For complete information, contact C. P. Clare & Co., 3101 Pratt Blvd., Chicago 45, Illinois. In Canada: C. P. Clare Canada Ltd., 2700 Jane Street, Toronto 15. Cable Address: CLARELAY

# CLARE RELAYS

FIRST in the industrial field



# DECISION MAKER

## for simplified monitoring, controlling, high-precision switching

Normal/abnormal . . . high/low . . . go/no-go: these are important decisions being made by A.P.I. Very High Sensitivity Measuring Relays.

Direct from sensory elements or circuits, the A.P.I. measuring relay makes a decisive "yes or no" decision on the basis of very close-tolerance voltage or current changes. In typical, critical applications, this measuring relay is saying "yes or no" on a change of ±1 microamp; or in a 400- to 500-volt circuit, on a variation of only a few percent.

Moreover, the relay is capable of actuating on very tiny currents: for example, total inputs as small as 0.2 microampere or 0.1 DC millivolt. It does so without signal amplification, amplifier costs or the signal distortion problems that often go along.

Performance stability is inherent; reliability is exceptional due to the A.P.I. locking-coil design. On "make", contact is firm with substantial contact pressure; contact resistance is low. On "break", separation is clean and quick without contact teasing.

10,000,000 perfect operations is not an all-time record; it's a reasonable expectation of service life.

Widely used for precision switching in computer, control and alarm circuits, VHS measuring relays are practically unlimited in scope of application.

*For more information, send for Bulletin 104-D.*

api **ASSEMBLY PRODUCTS, INC.**
**Chesterland 77, Ohio**

S-A. 1803-C

CIRCLE 47 ON READER-SERVICE CARD

## WHAT'S NEW

### TI Expands Eastward

**Merger with Metals & Controls had been shaping up for several months; description of the two companies shows how they complement each other.**

On April 15, stockholders of Texas Instruments, Inc., agreed to a merger plan shaped by their own company and Metals & Controls Corp., and approved five days earlier by stockholders of the latter firm, thus successfully concluding several months of negotiation (CtE, March, p. 56). Texas Instruments, says that company in a very complete brochure, will be the name of the surviving corporation. The brochure contains 40 pages on both companies. Examples:

About *Texas Instruments*—Incorporated as Geophysical Service, Inc., in 1930 in New Jersey, became Coronado Corp. in 1938. Coronado directed all its geophysical work into a subsidiary Geophysical Service, which in 1941 spun-off from the parent company to devote itself to exploration and the development and manufacture of seismic instruments and equipment. In 1951, with wartime work in electronic instruments behind it, the firm's name was changed once more, this time to General Instruments, Inc.; and once more, Geophysical Service became a subsidiary. The new parent devoted itself to manufacturing and R&D.

• **Became TI in 1951**—In December 1951, the parent changed its name again, becoming Texas Instruments, Inc. It then moved into high gear in what is today its principal businesses: manufacturing electronic and electromechanical systems and components, and semiconductor devices, and making geophysical explorations for the petroleum industry.

Early in 1958 (CtE, March '58, p. 44), TI contracted to furnish the bulk of IBM's transistors; a job like this is most likely to be handled by the TI Semiconductor-Components Div., which has done and is doing work in silicon and germanium transistors, diodes, rectifiers, precision resistors, and tantalum capacitors. Broad markets exist, or are developing for, these semiconductor devices.

The Apparatus Div. is prime contractor for various government agencies. It has worked on the Bomarc, Corvus, Falcon, Titan, Sidewinder, and other missiles, and has contributed

*Now from* **CLEVITE** . . .

# HIGH POWER TRANSISTORS

*Clevite offers new types with improved reliability and power handling capacity.*

**EIA REGISTERED TYPES WITH:**

- **Improved seal for long life.**
- **Saturation voltage less than 1 Volt at increased maximum rated current of 15 amperes.**
- **Average thermal resistance 0.7°C per watt.**
- **Current gain controls: 60-150 at 5 amperes.**
- **100% test for resistance to transient burn out.**
- **Either standard pins or solder lugs.**

**TECHNICAL DATA**

**Typical Electrical Characteristics at 25°C**

| 2N1147 Series has solder lugs<br>2N1146 Series has standard pins | 2N1147<br>2N1146 | 2N1147A<br>2N1146A | 2N1147B<br>2N1146B | 2N1147C<br>2N1146C |
|---|---|---|---|---|
| Collector to Emitter Voltage Shorted Base (IC = 1 amp) | 30V (Min) | 40V (Min) | 60V (Min) | 75V (Min) |
| Saturation Voltage (IC = 15 amps) | 1.0V (Max) | 1.0V (Max) | 1.0V (Max) | 1.0V (Max) |
| DC Current Gain (IC = 5 amps) | 60-150 | 60-150 | 60-150 | 60-150 |
| DC Current Gain (IC = 15 amps) | 35 | 35 | 35 | 35 |
| **Absolute Maximum Ratings** | | | | |
| Collector Current | 15 amps | 15 amps | 15 amps | 15 amps |
| Collector to Base Voltage | 40V | 60V | 80V | 100V |
| Collector to Emitter Voltage | 40V | 60V | 80V | 100V |
| Power Dissipation at 70°C Case Temperature | 25W | 25W | 25W | 25W |
| Junction Temperature | 95°C | 95°C | 95°C | 95°C |

**CLEVITE**
**TRANSISTOR PRODUCTS**
241 Crescent St., Waltham 54, Mass. TWinbrook 4-9330

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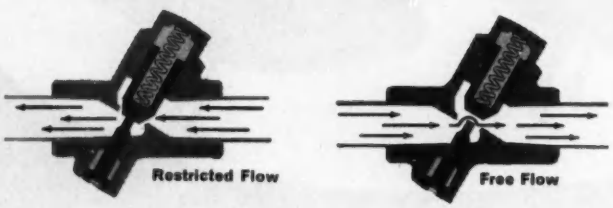
**CIRCLE 48 ON READER-SERVICE CARD**

# New Westinghouse FLOREG Valves for accurate flow control of gases and liquids




The new Westinghouse Floreg Valve accurately controls the rate at which a gas or liquid can flow in one direction through the circuit, yet allows free flow in the opposite direction. It works with other components of a fluid circuit to time, to sequence or to co-ordinate the operations of the circuit.

### Chief Advantages

**Easily adjustable in minute steps to full flow.**

**Greater capacity, lightweight and compact.**

**Consistent flow regulation: Single flow passage eliminates leakage encountered in separate check valve design.**

**Corrosion resistant: Made of aluminum, stainless steel and plated steel parts. Seals are oil-resistant.**

**Working pressure: 250 psi maximum pneumatic, 500 or 2000 psi maximum hydraulic.**

**Easily inspected and maintained: No need to break circuit connection.**

**Operating temperature range: —40 ° to 200 ° F.**

**Three sizes: ¼", ⅜", and ½", N.P.T.**

**Prices start at $4.00 on the ¼" size weighing 2.5 ounces.**

### Applications

. . . In the delivery line to a cylinder to control its piston speed.

. . . In material processing to time operations.

. . . In material handling to co-ordinate movement.

. . . In the speed line of a diesel engine to control acceleration rate.

*See the yellow pages under cylinders for the name of your local distributor*

**WESTINGHOUSE AIR BRAKE COMPANY**
*Industrial Products Division, Wilmerding, Pennsylvania*

**CIRCLE 49 ON READER-SERVICE CARD**




developments in the measurement of torque and operating temperature.

• **Lab crosses the board**—A specialized activity, the Central Research & Engineering Laboratory, functions independently to coordinate all research projects, particularly those that can be characterized as long-term. Specifically, this means research in solid-state physics, materials, electronic devices, data systems, and earth sciences. In 1958, the company spent $16 million for research, engineering, and development.

Both divisions and the CRE Laboratory are located in Dallas; but TI has facilities at Houston, too, and in Bedford, England. Total personnel: 7,500. In 1958, it had net sales of

## Raytheon-Machlett Merger Needs Stockholders' Blessing

Stockholder approval is needed to tie together Raytheon Mfg. Co. and Machlett Laboratories, Inc. Directors already have blessed the merger, which would bring Machlett into the Raytheon family as a division. The $10-million-a-year Springdale, Conn., firm manufactures high-power, high-voltage electron tubes for industry and the military. Raytheon, with $375 million a year in sales, sees no overlap in products between itself and Machlett.

* * *

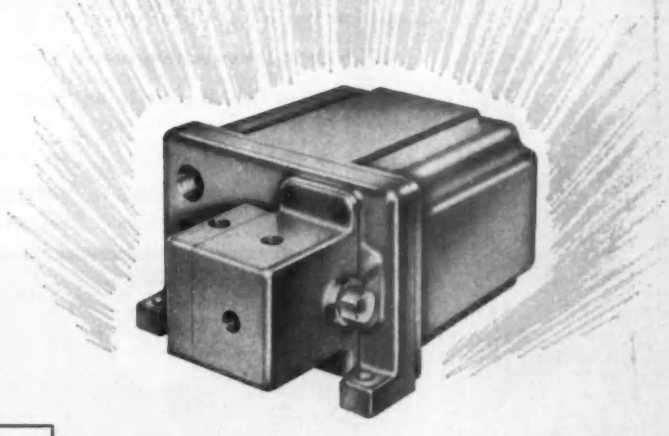
Merger negotiations are also under way in Melbourne, Fla., with the end in view being the affiliation of Radiation, Inc., of that city, and Levinthal Electronic Products, Inc., of Palo Alto, Calif. Radiation, known for its telemetry and digital data processing systems, would be the ascendant firm; Levinthal, manufacturer of radar, and electro-surgical, medical, and nucleonic equipment, would become a Radiation subsidiary.

## Computer-Measurements Sold to Firm Outside the Field

Computer-Measurements Corp. of North Hollywood, Calif., manufacturer of counting and time- and frequency-measuring equipment, has been purchased by Pacific Industries, Inc., of San Francisco. The acquisition signals Pacific Industries' entrance into the electronics field; its interests heretofore have been in furnace manufacturing, ship-repairing, film-processing, leather-tanning, and uranium mining.

New from **GPE Controls...**

Model 776F **Flow Transmitter** has the lowest differential pressure requirement of any transmitter...as low as 3" w.c. for maximum output of 25 volts d.c. at power levels up to 5 watts. Permits use of larger orifices; transmission over as much as 5 miles; simultaneous operation of controllers, recorders, analog-to-digital converters. Automatically extracts square root for straight summarization of flows. Also Model 776D for differential pressure transmission.



GPE Controls | A GENERAL PRECISION COMPANY

*Write for descriptive literature*

**GPE Controls, Inc.** (formerly Askania Regulator Company)
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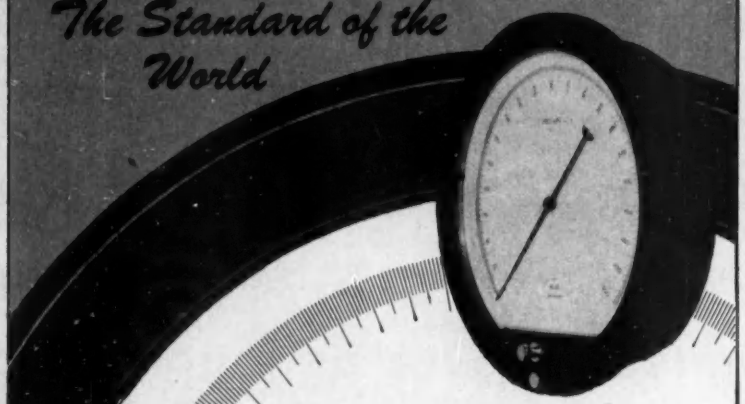
# HEISE GAUGES

*The Standard of the World*



**Heise Laboratories specialize in the manufacture of precision laboratory instruments for critical fluid pressure applications.**

**The Heise Gauge is a world recognized standard for pressure measurement used by many laboratories in place of the dead weight tester for reference data.**

**Heise Engineers are always available for advanced research and development. Prompt and skillful attention to inquiries in the precision pressure instrument field is a Heise tradition.**

| PRESSURE RANGES | DIAL SIZES | PRICES |
|---|---|---|
| 15 to 50,000 P.S.I. | 8½"-12"-16" | from $166.75 |

**DELIVERY within 30 days**

**HEISE BOURDON TUBE COMPANY, INC.**
BROOK ROAD, NEWTOWN, CONNECTICUT, U.S.A.

CIRCLE 51 ON READER-SERVICE CARD


## WHAT'S NEW

$136,348,773, net income of $7,869,-184, and a backlog of $61,400,000. Comparable figures in 1957 were $103,542,055, $5,639,798, and $31,-400,000.

About Metals & Controls — Grew out of the association in 1931, of two Attleboro, Mass., companies, General Plate Co. (rolled gold plate and gold-filled material for the jewelry industry) and Spencer Thermostat Co. (principally a snap-acting disc made of thermostatic material.) Today, M&C's control-field contributions include thermostatic and electric controls for appliances and motors, and nuclear fuel elements and cores. In 1958, net sales came to $44,394,928, net income to $1,868,256; in 1957, the figures were $36,203,481 and $1,574,322. (Significantly, both companies made profits in all categories in the recession year of 1958.)

• **The Klixon line**—M&C's Thermostat Div. manufactures motor protectors, motor-starting relays, circuit breakers, thermostats, and precision switches, all under the trade-mark, Klixon. Motor protectors constitute about half the division's sales. The Versailles Products Div., at Versailles, Ky., complements the Thermostat Div. line with appliance thermostats, also makes some Klixon products.

In 1957, when it was recognized that the volume of nuclear activities of the General Plate Div. had expanded beyond the scope of this division, these activities were transferred into their own unit, which in 1958 became the subsidiary M&C Nuclear, Inc. Its advancements, before and after subsidiary status, have involved fuel components for the nuclear submarine Sea Wolf, nuclear fuel cores for the submarine Triton. Work is also in progress on two larger cores for aircraft and cruisers; delivery date: 1960.

• **Wide-spread**—M&C has main offices in Attleboro, Mass., and Versailles, Ky., sales offices in New York City, Detroit, Indianapolis, Chicago, Milwaukee, and Los Angeles; and foreign subsidiaries in Mexico, Argentina, Holland, France, Italy, Germany, and Switzerland. It employs 3,600 people.

The chief executives of the surviving company include the following: J. Erik Jonsson, chairman of the board; Eugene McDermott, chairman of the executive committee; Patrick E. Haggerty, president; Cecil H. Green, vice-president; Fred J. Agnich, president of Geophysical Service, Inc.; S. T. Harris, vice-president, marketing; W. F. Joyce, vice president, appar-

*cppc* ***Progress Report:***

# ENVIRONMENT

## Shock . . . . . 80 g's

## & Vibration . . . . . 20 g's 0 to 2000 cps

Special synchros have been designed at Clifton Precision to meet shock requirements as high as 80 g's. Vibration requirements involving 0 to 2000 cps and 20 g's have also been met. Clifton's versatility in the design of brushes and slip rings has permitted us to meet very exacting customer specifications. Let us know your requirements!

## Temperature . . . . . 800° F

A year and a half ago we announced our synchros for direct turbo jet engine mounting which successfully resist 450°F. Since then we have progressed to where we are developing synchros that withstand 800°F for short periods and retain their precision characteristics.

Our high temperature resistant line of synchros can now be obtained in sizes 8, 10 and 11. High temperature units also available in our servo motors, motor generators and precision computing resolvers.

**SIZE 8 SYNCHRO**
ACTUAL SIZE

## Radioactivity . . . . . 1 Kilocurie for 2 weeks

We recently delivered radioactivity resistant synchros to a manufacturer of radioactive material handling equipment. When tested, these synchros successfully resisted unremitted radiation from 1 Kilocurie of Cobalt 60 for 2 weeks. The synchros remained functional in all respects i.e. accuracy, nulls, lubrication, insulation unimpaired.

For information call or write: Sales Department, 9014 West Chester Pike, Upper Darby, Pa. (Suburban Philadelphia.) HIlltop 9-1200 or our Representatives.

***LOOK TO CPPC for ANY ROTARY COMPONENT***

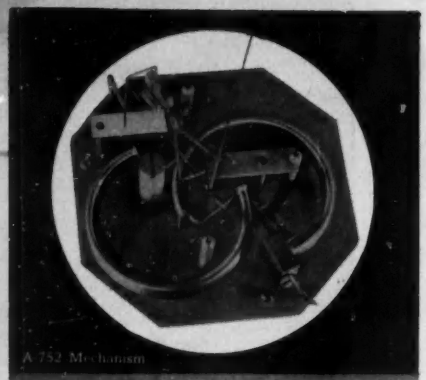
*cppc*

**CLIFTON PRECISION PRODUCTS CO., INC.**

**CLIFTON HEIGHTS, PA.**

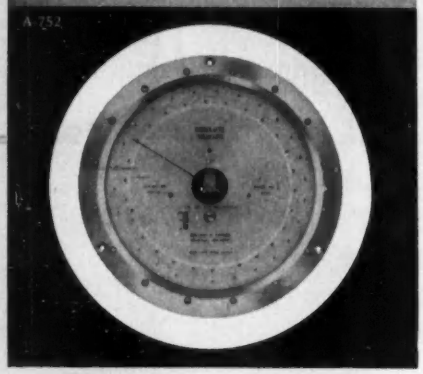
**ENGINEERS—Do you want rapid growth as an "extra" in your career?**
**Write David D. Brown, Personnel Director, Dept. N5**

**CIRCLE 52 ON READER-SERVICE CARD**



A-752 Mechanism

NEW W&T BOURDON TUBE GAUGE



A-752

***liquid column accuracy beyond liquid column range***

**A combination of Ni-Span-C* Bourdon tubes, a special ratio linkage and custom calibration set these W&T gauges apart. Use of corrosion-resistant Ni-Span-C eliminates temperature compensation, makes the gauge usable in a wide variety of applications. Dual Bourdon tube mechanism provides high accuracy measurements of absolute or differential pressures without applying any system pressure to the gauge case. The special ratio linkage provides low friction, practically no hysteresis. Custom calibration means rapid, accurate readout, as in all W&T precision pressure instruments.**

***W&T Bourdon tube gauges have:***

**Max. Range—0-500 p.s.i.; absolute, gauge or differential**
**Min. Range—0-30 p.s.i.; absolute, gauge or differential**
**Sensitivity—1:8000**
**Accuracy—0.2% of full scale range**
**Hysteresis—negligible**
**Temperature effect—0.075% of range/10°C**

***For full information and technical data address Dept. A-123.28***

**WALLACE & TIERNAN INCORPORATED**
25 MAIN STREET, BELLEVILLE 9, NEW JERSEY
IN CANADA: WALLACE & TIERNAN LTD., WARDEN AVE., TORONTO 13, ONT.
*REGISTERED TRADEMARK, INTERNATIONAL NICKEL CO.

**CIRCLE 53 ON READER-SERVICE CARD**

**IF IT'S FREE FLOWING AND DRY**

we have accurate reliable means of feeding it. For information about these dry chemical feeders *both gravimetric and volumetric...*

Write Dept. M-42.28

**WALLACE & TIERNAN INCORPORATED**
25 MAIN STREET, BELLEVILLE 9, NEW JERSEY

**CIRCLE 54 ON READER-SERVICE CARD**


## WHAT'S NEW

atus; R. W. Olson, vice-president, research and engineering; Mark Shepherd Jr., vice-president, semiconductor components; and Bryan F. Smith, secretary and treasurer.

### List of Speakers for ISA Sections Is Worth Having

A splendid example of excellent organization is a list of speakers prepared for its sections by ISA. The list carries about 110 names (there are 118 entries, but some appear more than once) under 19 subject headings. Accompanying each name are the speaker's company and position, the title of his talk and the time it takes to give it, the type of illustrations he used (slides or blackboard primarily), and the distance he is willing to travel.

Most of the speakers indicate they do not expect reimbursement. And many who so indicate will speak anywhere in the U.S.

The 19 subject-specialities of the speakers are: analysis instrumentation, data handling and computation, feedback control systems, instrumentation electronics, instrument installation, operation, and maintenance, management and economics, measurement and control instrumentation, physical and mechanical measurement, and aeronautical instrumentation.

Also, chemical and petroleum instrumentation, food instrumentation, instruments manufacture, medical and biological instrumentation, metals and ceramics instrumentation, power industry instrumentation, pulp and paper instrumentation, rubber and plastics instrumentation, scientific laboratories instrumentation, and transportation instrumentation.

A section program chairman eager to plan a "horizontal" year of meetings could do worse than build activities around this list. A judicious selection of speakers from its 19 categories will answer most needs.

### New Companies in the Field

**Advanced Technology Laboratories,** formed by American Radiator & Standard Sanitary Corp. to expand American-Standard's work in industrial and military research, development, and engineering, and to further its interests in atomic energy — in Mountain View, Calif. Specific areas will include nuclear physics, metal-

(Continued on page 187)

TINY TEAMMATE FOR STRAIN GAGES

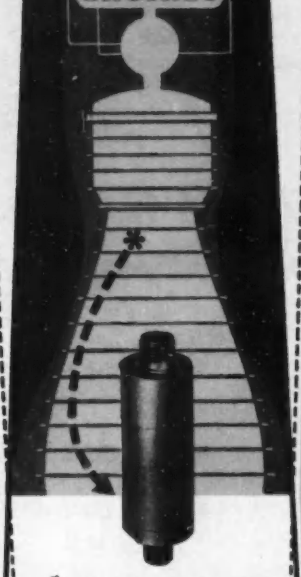
**STATHAM CA 9 Strain Gage Signal Amplifier**

Through the use of modern design techniques, Statham has succeeded in drastically reducing the size and weight of strain gage signal amplifiers. Completely transistorized, the CA 9 is more reliable in adverse environments than larger and heavier amplifiers, and retains the precision needed in current aircraft and space vehicles. Write for Data File CE-601-1.

STATHAM INSTRUMENTS, INC.
12401 West Olympic Boulevard
Los Angeles 64, California

Statham

THRUST SENSING FOR LIQUID ROCKET ENGINES



***STATHAM PA324 Pressure Transducer**

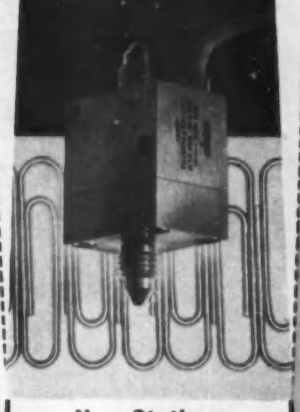
Because of its outstanding performance in severe missile environments, the Statham Model PA324 Absolute Pressure Transducer has been chosen to play the key role in important new thrust control systems based on accurate measurement of thrust chamber pressure. For further information write for Data File CE-600-2.

STATHAM INSTRUMENTS, INC.
12401 West Olympic Boulevard
Los Angeles 64, California

Statham

STATHAM ANNOUNCES

HIGH OUTPUT MINIATURE UNBONDED STRAIN GAGE



**New Statham Pressure Transducers With ¼ Volt Output**

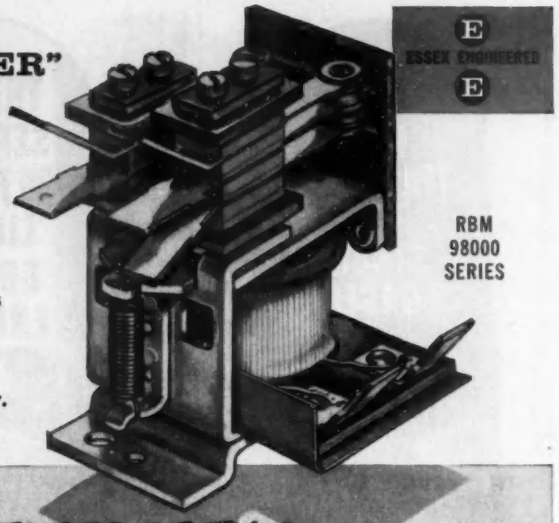
Statham's continuous product development has now provided the flight instrumentation engineer with subminiature transducers which are compatible with present day high level commutators. The ¼ volt output makes it possible to simplify instrumentation systems and at the same time provide the accuracy, reliability and service life characteristic of the unbonded strain gage. Write to Dept. CE-602-1.

STATHAM INSTRUMENTS, INC.
12401 West Olympic Boulevard
Los Angeles 64, California

Statham

# SMASH THE "DESIGN BARRIER" AND STILL LOWER YOUR FINISHED PRODUCT COST!

Since the basic relay and its many contact forms, ratings, and terminal variations are regular production items at RBM, design bottlenecks can be shattered. RBM has "CUSTOMERIZED" these relays to fulfill almost every conceivable requirement. This vast background of application engineering can serve you with design shortcuts . . . lower your "finished product" cost. Ask your RBM product application engineer.

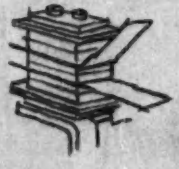



RBM 98000 SERIES

## CHECK THE FEATURES OF THIS RBM AC OR DC GENERAL PURPOSE RELAY

MANY ARE LISTED BY U/L FILE NOS. E12139 OR E22381

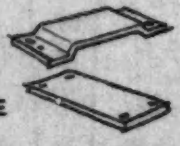
PRESSFIT PILE-UP ELIMINATES DRIFT; ASSURES CONTACT STABILITY



DEPENDABLE CROSS-BAR CONTACTS AVAILABLE FOR LOW VOLTAGE AND/OR LOW CURRENT CIRCUITS

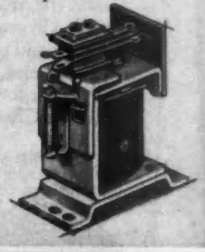
SIMPLIFIED MAGNET FRAME AND ARMATURE ASSEMBLY PROVIDES EFFICIENT, POSITIVE ACTION

VARIETY OF MOUNTINGS AVAILABLE



| OTHER FEATURES | A.C. 98700 TYPE | D.C. 98600 TYPE |
|---|---|---|
| • MAX. COIL VOLTAGE | 230AC | 115 DC |
| • MAX. COIL RES. IN OHMS | — | 20000 |
| • MAX. COIL WATTS OR VOLT AMPS. | 9.0 V.A. INRUSH 6.5 V.A. SEALED | 4.0 W. |
| • MAX. CONTACT FORM WITH RATED CURRENT AT 32 V. DC OR 115 V. AC (NON-INDUCTIVE LOAD) | 2PDT 15 AMPS. 4PDT 6 AMPS. 6PDT 3 AMPS. | 2PDT 15AMPS. 4PDT 6AMPS. 6PDT 3AMPS. |
| • APPROX. WEIGHT | 4.1 OZ. | 4.1 OZ. |

ALSO AVAILABLE IN 97000 SERIES PROVIDING ADDITIONAL COIL POWER... GREATER SENSITIVITY



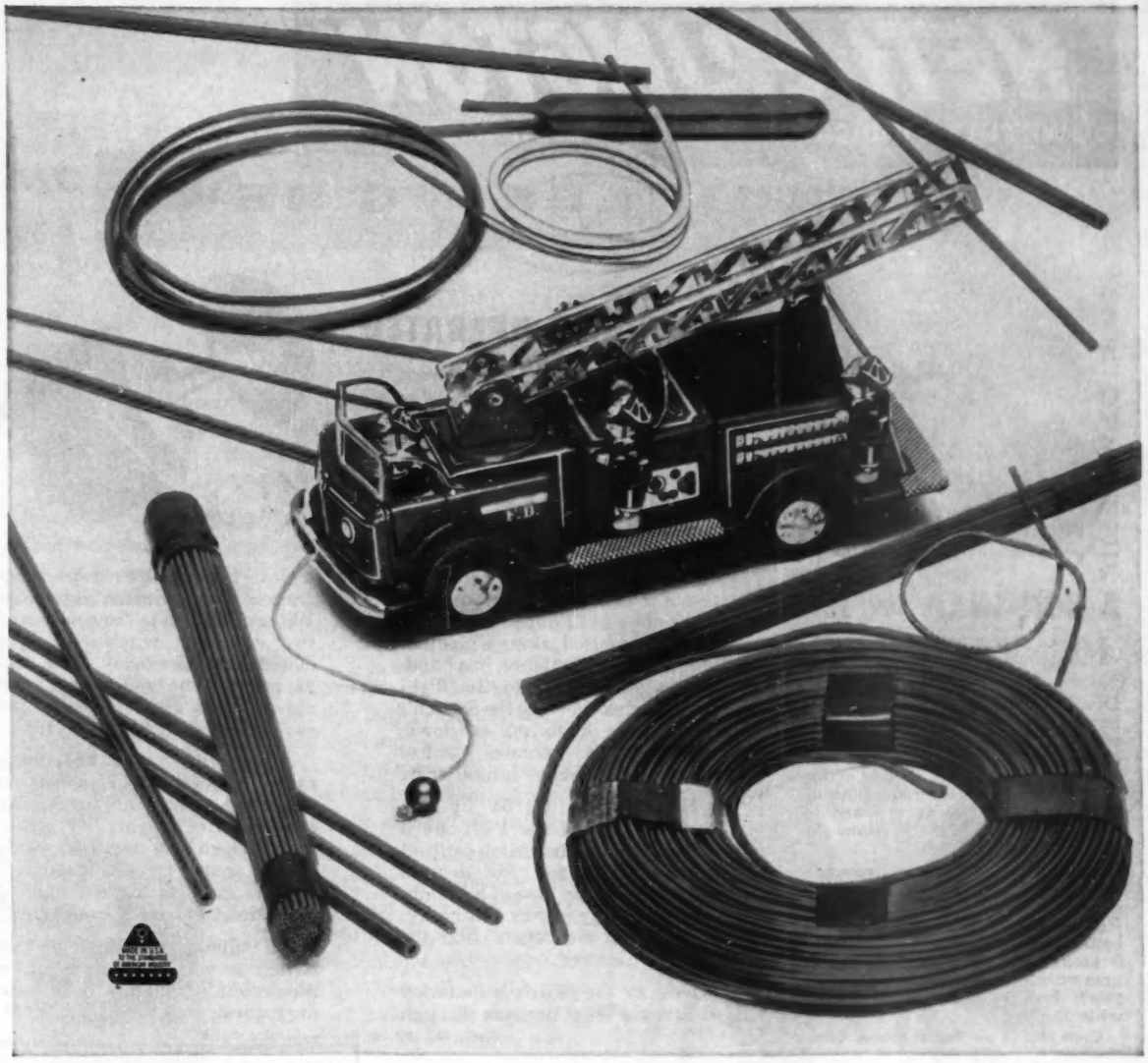
*Consult Your Local RBM Product Application Engineer or Write For Bulletin 1060*

RBM

**RBM Controls Division**

ESSEX WIRE CORPORATION, LOGANSPORT, INDIANA

Factories Located at Peru, North Manchester and Logansport, Indiana



## KENSICO HELPS STOP FIRES BEFORE THEY SPREAD!

Kensico's precision-drawn copper capillary tube does just that—as an *integral part* of one of today's leading automatic fire detection systems. Effective fire detection and prevention of fire loss is dependent on overall *tube quality* and workmanship. Close Tolerances. Inside Surfaces. Uniform Flow. Exact Specifications. Tube Cleanliness. Why not try Kensico for your *next small tube application*? Write now for Free Flow Charts. Engineering Consultation also available.

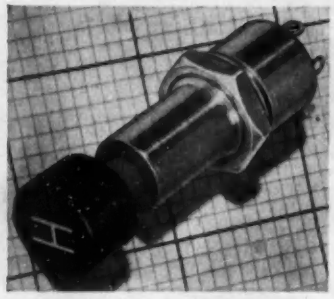
CAMBRIDGE, MASS. • BUFFALO, N. Y.
LINDENHURST, N. Y. • GOSHEN, N. Y.
ROSELLE, N. J. • PHILADELPHIA, PA.
PITTSBURGH, PA. • CLEVELAND, OHIO
DETROIT, MICH. • EVANSTON, ILL.
ST. LOUIS, MO. • MILWAUKEE, WISC.
DURHAM, N. C. • FT. LAUDERDALE, FLA. • ST. PETERSBURG, FLA.

**Kensico Tube**
COMPANY INCORPORATED, MT. KISCO, N. Y.

# HETHERINGTON

SWITCHES • INDICATOR LIGHTS • SPECIAL ASSEMBLIES

## ENGINEERING NEWS



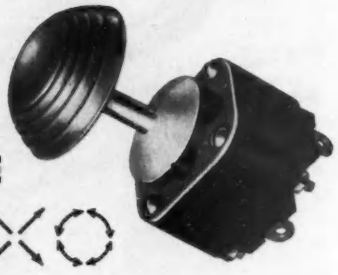
## A NON-SNAP SWITCH FOR "KEYBOARDS"

Developed specifically for the keyboards of electronic computers, calculators, and other business machines, the Hetherington B5023 gives the smooth, yet precise action necessary for fast manipulation. Operating pressure is a scant ½ pound — just enough to retain the familiar keyboard "feel."

The versatile 2-circuit, momentary-contact circuitry of the B5023 can also be used as SPST or SPDT. Recent tests have shown a life of better than 1.7 million operations at 5 amps., 30 volts dc. This is far greater than the conservative rating you'll find in Bulletin S-6 if you write for it.

**Circle No. 58 on Reader-Service Card**

## THUMB-OPERATED "TOGGLE" CONTROLS 4 SEPARATE SWITCHES



A familiar sight to helicopter pilots is this versatile Hetherington Type F441 Four-Way Switch. Here it is housed, along with other Hetherington Switches, in a handgrip which fastens to the flight control stick. Moving the Switch's thumb-type knob up or down, right or left, operates control motors for hoists or lateral trim.

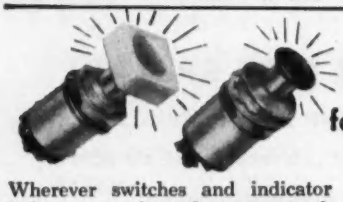
Housed in the 1-1/64" by 7/8" phenolic case of the F441 are 4 separate momentary-contact switches arranged 90 degrees apart around the base of a thumb-controlled toggle lever. Normally, all switches are "open" and the toggle is centered.

Usually the switch is mounted so that the lever projects through a cloverleaf gate that restricts operation to one switch at a time. Without the gate however, any two adjacent switches may be closed simultaneously. The toggle may also be held outward and moved in an arc to actuate all 4 switches in succession.

Admittedly, the F441 Switch is rather specialized. However, it offers industrial users interesting opportunities to simplify equipment design and operation — by saving space, by "foolproofing" critical circuits, or by making operations easier to understand.

No bulletin is available on this switch as yet, but ratings and a dimension drawing will be sent on request. Ask about the F441.

**Circle No. 59 on Reader-Service Card**



## *New* SWITCHLITES® for "Human-Engineered" Panels

Wherever switches and indicator lights are used on the same panel, Hetherington *Switchlites* can play a major part in improving panel legibility and operating convenience. For the pushbuttons of these compact snap-action switches contain their own *built-in* indicator lights for easy, direct association of switch and light functions. Moreover, they save greatly on panel space, wiring, installation and removal time.

So many different Hetherington *Switchlites* are now available that only a few of their many features can be mentioned here:

**Switch Circuits:** SPST, SPDT, DPST, DPDT, or 2-circuit. Up to 15 amps @ 28 v. dc.

**Snap-Action:** Push, momentary; Pull, momentary; Push-Pull, maintained; Push-Push, maintained; Push-Pull, maintained with auxiliary momentary on "push."

**Lamp Circuit:** Case ground or separate gnd. terminal. "Hot" lead to separate terminal, thru main sw. contacts, or thru separate built-in sw. circuit. 6, 14, 18, 28 volt AN3140-type lamps.

**Pushbutton Lenses:** 10 styles, each in 10 transparent or translucent colors. Lettering may be engraved on all.

New Bulletin S-7 gives complete details on all Hetherington *Switchlites*.

**Circle No. 60 on Reader-Service Card**

## NOW! AT LEADING PARTS DISTRIBUTORS

**Need Hetherington products for prototypes, breadboard models, special projects, or small production runs? Most popular Hetherington items are available at local electronic parts distributors everywhere.**

For the name of your nearest parts distributor and bulletins of the Hetherington Switches, Indicator lights, and *Switchlites* he carries, write *directly* to: **DISTRIBUTOR'S DIVISION, HETHERINGTON INC., 26 Rittenhouse Place, Ardmore, Pa.**

**HETHERINGTON INC.** DELMAR DRIVE, FOLCROFT, PA. • 139 Illinois St., El Segundo, Calif.

*better switch engineering for a pushbutton world*

A Controls Company of America Subsidiary

*Save time . . . insure accuracy*

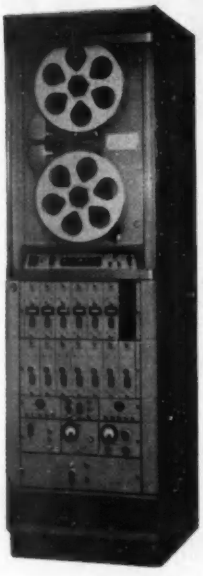
# MONITOR YOUR TAPE DATA

*with integrated amplifier meters*

SEVEN TYPES OF PLUG-IN AMPLIFIERS ARE AVAILABLE IN THE 5-752 SYSTEM TO RECORD OR REPRODUCE IN ANALOG, FM OR PDM MODES.

CEC's new record and reproduce amplifier meters mount *directly* on individual Analog or FM amplifiers of the standard 5-752 Magnetic-Tape Recorder/Reproducer System . . . to save time and assure accuracy. On *record* amplifiers, the meters allow continuous monitoring of incoming signals. On *reproduce* amplifiers they are used to monitor output signals and to provide positive indication that test data are being recorded on tape.

Mounting of the meters directly on the amplifier panels significantly reduces the possibility of stray pickup being mixed with signals and also eliminates the confusion in channel identification that often occurs when meters are remotely located. The monitor meters do not adversely affect the recorded signals or normal operation of the amplifiers.



By providing a means of locally adjusting signal and bias levels, the meters are invaluable when setting up the 5-752 prior to a test run. On Analog record amplifiers, the units can be used to monitor bias signal level by means of a front panel selector switch.

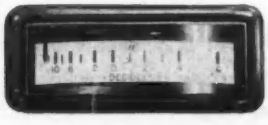
CEC's 5-752 Magnetic-Tape Recorder/Reproducer System provides up to 14 tracks of precision data recording and playback of frequencies from d-c to 100 kc. The 5-752 is widely used in industrial, medical and military applications. Among its features are all-metal-surface magnetic head stacks . . . six standard IRIG tape speeds . . . lowest cumulative flutter characteristics.

*For complete information on the 5-752 system and CEC Amplifier Monitor Meters, contact your nearest CEC sales and service office or write for Bulletin CEC 1576-X38.*

*DataTape Division* CEC

**CONSOLIDATED ELECTRODYNAMICS** *300 N. Sierra Madre Villa, Pasadena, Calif.*

FOR EMPLOYMENT OPPORTUNITIES WITH THIS PROGRESSIVE COMPANY, WRITE DIRECTOR OF PERSONNEL



METERS ARE AVAILABLE ON CEC ANALOG OR FM RECORD AND REPRODUCE AMPLIFIERS AS FACTORY INSTALLED OPTIONAL EXTRAS, OR THEY MAY BE ORDERED IN KIT FORM FOR INSTALLATION BY THE USER. KITS INCLUDE METER, NEW AMPLIFIER FRONT PANEL AND FULL INSTALLATION INSTRUCTIONS.

CIRCLE 61 ON READER-SERVICE CARD

# BOILING HEAT

...or

# FREEZING COLD

## ...Hold it Constant with RCA Thermoelectric Junctions!

**RCA offers new solid-state device capable of maintaining constant control of "zone" temperature below or above ambient.**

Holding a "zone" at a constant temperature...*despite wide variations in ambient*...often demands heating or cooling systems that are complex. Usually a compromise is employed, resulting in controlling temperature at a point *above* ambient. To hold temperature *below* ambient requires refrigerants, ice packs, or forced liquid cooling. These techniques have inherent limitations.

Now, RCA announces developmental Thermoelectric Elements...unique and extremely compact devices capable of producing "boiling heat" or "freezing cold" in small "zones". Circuitry is simple. You have infinite control from maximum cooling to maximum heating through variations of the dc power supplied to one device. With no moving parts, vibration is eliminated—long life assured.

RCA Thermoelectric Junctions are excellent for service in laboratory "ovens" or "cold chambers". The new elements make practicable, for the first time, the manufacture of simple and completely transportable temperature-control apparatus capable of holding temperatures constant *below* ambient.

**EAST**
744 Broad St., Newark, N. J.
HUmboldt 5-3900

**NORTHEAST**
64 "A" Street, Needham Heights 94, Mass.
Hillcrest 4-7200

**EAST CENTRAL**
714 New Center Bldg., Detroit 2, Mich.
TRinity 5-5600

**CENTRAL**
Suite 1154, Merchandise Mart Plaza
Chicago, Ill. WHitehall 4-2900

**WEST**
6355 E. Washington Boulevard
Los Angeles, Calif. RAymond 3-8361

**GOVERNMENT**
224 N. Wilkinson St., Dayton, Ohio
BAldwin 6-2366
1625 "K" Street, N.W., Washington, D.C.
District 7-1260

*For information on developmental samples, please contact the RCA sales office nearest you, or, write direct to RCA Commercial Eng., SectionE-56-NN,Somerville, N. J.*

**RADIO CORPORATION OF AMERICA**
**Semiconductor & Materials Division**
**Somerville, N. J.**

basic tool for process measurements . . .

# FOXBORO d/p CELL* TRANSMITTERS

Positive overrange protection . . . no perceptible zero drift . . . high sustained accuracy, even under the most punishing operating conditions.

D/p Cell bodies are available in 316 s.s. or rustproofed carbon steel. Unique stainless steel twin-diaphragm capsule is specifically designed to provide positive overrange protection. Purged cover protects transmitter from weather, dust, and fumes.

You can install d/p Cells anywhere — in any position — simply and conveniently, and know they'll give unequaled accuracy and performance. Ask your Foxboro Field Engineer for complete details, or write for Bulletin 13-11A. **The Foxboro Company, 365 Norfolk Street, Foxboro, Mass.**

## Foxboro d/p Cells for flow, liquid levels, and other variables

- for high-speed flow measurement and control
- for flow measurement as small as 0.03 gpm
- for flow under static pressures to 6000 psi
- for use where elevated or suppressed ranges are required
- for electronic flow control systems
- for liquid level
- for comparison of process and sample fluids
- for absolute pressure measurement

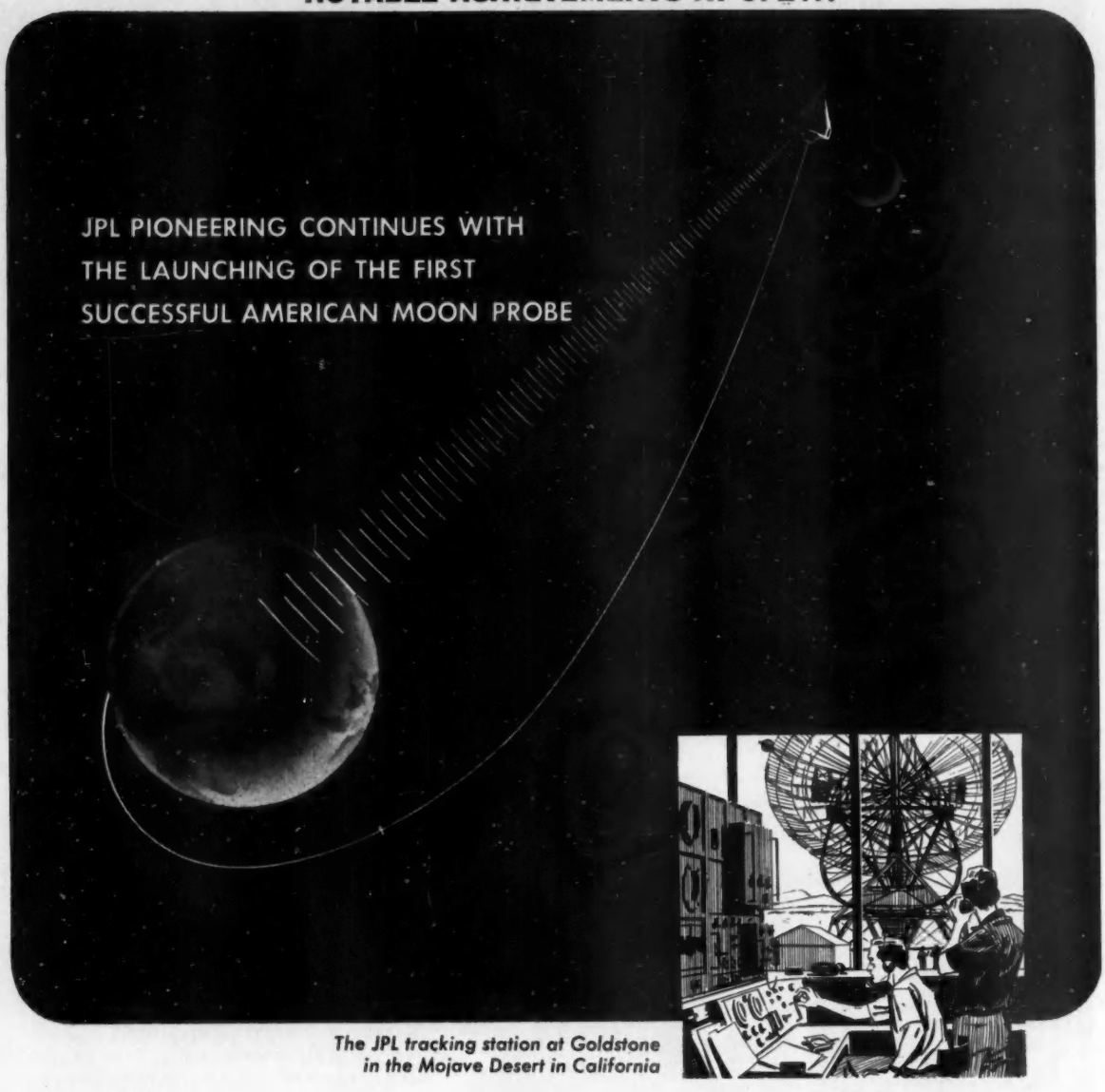
*Reg. U. S. Pat. Off.

**Foxboro Type 13A d/p Cell Flow Transmitter**
Three fully adjustable ranges:
0-5 to 0-25 inches of water
0-20 to 0-250 inches of water
0-200 to 0-850 inches of water
Working pressures of 500, 1500, and 6000 psi

FOXBORO
REG. U.S. PAT. OFF.

CIRCLE 62 ON READER-SERVICE CARD

## NOTABLE ACHIEVEMENTS AT JPL...




*The JPL tracking station at Goldstone in the Mojave Desert in California*

Early on March 3, 1959, Pioneer IV space probe was launched from Cape Canaveral, Florida to become America's first deep-space vehicle capable of escaping the earth's gravitational pull. On its way past the moon and out into orbit around the sun, this new man-made planet sent back valuable information on the radiations present in space. Several Free World tracking stations clearly received its transmitted signal and helped to establish its distance, velocity, and direction.

Under the sponsorship of the National Aeronautics and Space Administration, JPL designed and built not only the conical payload of Pioneer IV but also the three upper stages of the Juno II launching vehicle, containing new high-performance JPL solid propellant rockets.

Over a year ago the same JPL team, in cooperation with ABMA, gave America its first earth satellite, Explorer I, using a similarly reliable vehicle – the Jupiter C.

Now, more advanced space vehicle programs are under way at JPL — programs which include development of guidance and propulsion systems for accurate maneuvers many million miles from the earth.

jpl

CALIFORNIA INSTITUTE OF TECHNOLOGY

**JET PROPULSION LABORATORY**

A Research Facility of the National Aeronautics and Space Administration

**PASADENA, CALIFORNIA**

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 CIRCLE 63 ON READER-SERVICE CARD

# AN IMPORTANT *NEW* VHF-UHF INSTRUMENT

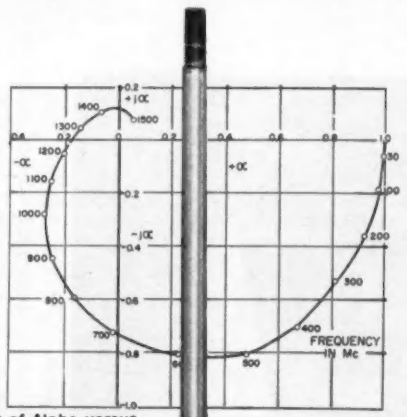
★ Measures Directly All Complex Impedance, Admittance, and Transfer-Functions of:

| TRANSISTORS | VACUUM TUBES | THREE- AND FOUR-TERMINAL NETWORKS |
|---|---|---|
| $\alpha$, $\beta$, $h_f$, $h_r$, $h_i$, $h_o$, $r'_b$, all short-circuit admittance and open-circuit impedance parameters. | $Y_m$ ($Y_{21}$), $Y_{12}$, $Y_{11}$, $Y_{22}$, etc. | $Z_{11}$, $Z_{22}$, $Z_{21}$, $Z_{12}$ $Y_{11}$, $Y_{22}$, $Y_{21}$, $Y_{12}$ $I_2/I_1$, $I_1/I_2$, $E_2/E_1$, $E_1/E_2$ |

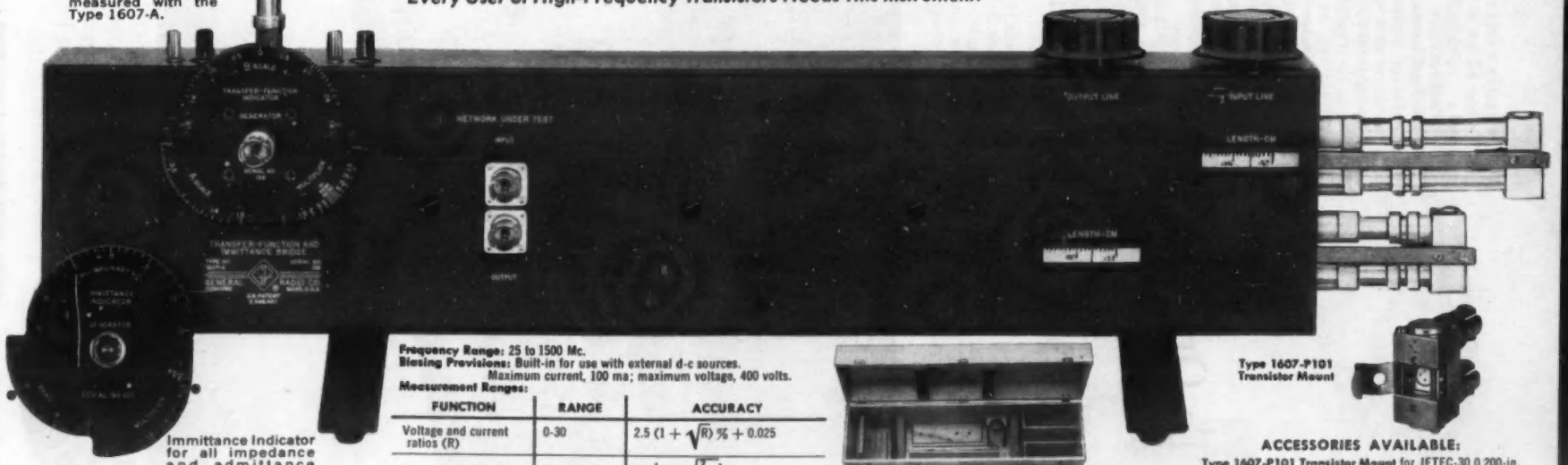
★ A Basic Tool for Measurement of: Gain and Phase Shift of Amplifiers, Transmission Circuits, and Other Active and Passive Four-Terminal Networks; Impedance, Admittance, Reflection Coefficient, and VSWR of Components, Coaxial Systems, and other Grounded or Ungrounded Elements.

★ Equally Suited for Advanced Laboratory Investigations and Rapid-Quantity Production Testing

***Every User of High-Frequency Transistors Needs This Instrument.***




Plot of Alpha versus frequency for an experimental high-frequency transistor . . . measured with the Type 1607-A.



Immittance Indicator for all impedance and admittance measurements.

**Type 1607-A Transfer-Function and Immittance Bridge, $1665.**

**Frequency Range:** 25 to 1500 Mc.
**Biasing Provisions:** Built-in for use with external d-c sources. Maximum current, 100 ma; maximum voltage, 400 volts.
**Measurement Ranges:**

| FUNCTION | RANGE | ACCURACY |
|---|---|---|
| Voltage and current ratios (R) | 0-30 | $2.5\,(1+\sqrt{R})\,\% + 0.025$ |
| Transimpedance ($Z_{21}$) | 0-1500 ohms | $2.5\left(1+\sqrt{\frac{Z_{21}}{50}}\right)\% + 1.25$ ohms |
| Transadmittance ($Y_{21}$) | 0-600 mmhos | $2.5\left(1+\sqrt{\frac{Y_{21}}{20}}\right)\% + 0.5$ mmho |
| Impedance ($Z_{11}$) | 0-1000 ohms | $2.0\left(1+\sqrt{\frac{Z_{11}}{50}}\right)\% + 1.0$ ohm |
| Admittance ($Y_{11}$) | 0-400 mmhos | $2.0\left(1+\sqrt{\frac{Y_{11}}{20}}\right)\% + 0.4$ mmho |

**ACCESSORIES SUPPLIED:**
Frequency-Range Extension Unit; Two Calibrated Transfer-Function and Immittance Indicators; Terminations; Standards; 10-db Attenuator; Air Lines, Patch Cords, and other Coaxial Elements.



Type 1607-P101 Transistor Mount

**ACCESSORIES AVAILABLE:**

**Type 1607-P101 Transistor Mount** for JETEC-30 0.200-in. pin-circle triode with grounded-base arrangement. **$60.**

**Type 1607-P102 Transistor Mount** for JETEC-30 0.200-in. pin-circle triode with grounded-emitter arrangement. **$60.**

**Type 1607-P201 Tube Mount,** 7-pin miniature, grounded cathode for 6AF4, 6AF4A, 6AN4, 6T4, and other tubes with the same pin connections **$75.**

Other mounts for tetrodes, 0.100-in. pin-circle triodes, and ungrounded components are in development and will be announced soon.

**Generator and Detector:** G-R Unit Oscillators and Type DNT Detectors are recommended.

# GENERAL RADIO COMPANY

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CIRCLE 64 ON READER-SERVICE CARD

# Ten To One

## *New Fenwal Monitor simultaneously brings 10 remote temperature signals to one central location*

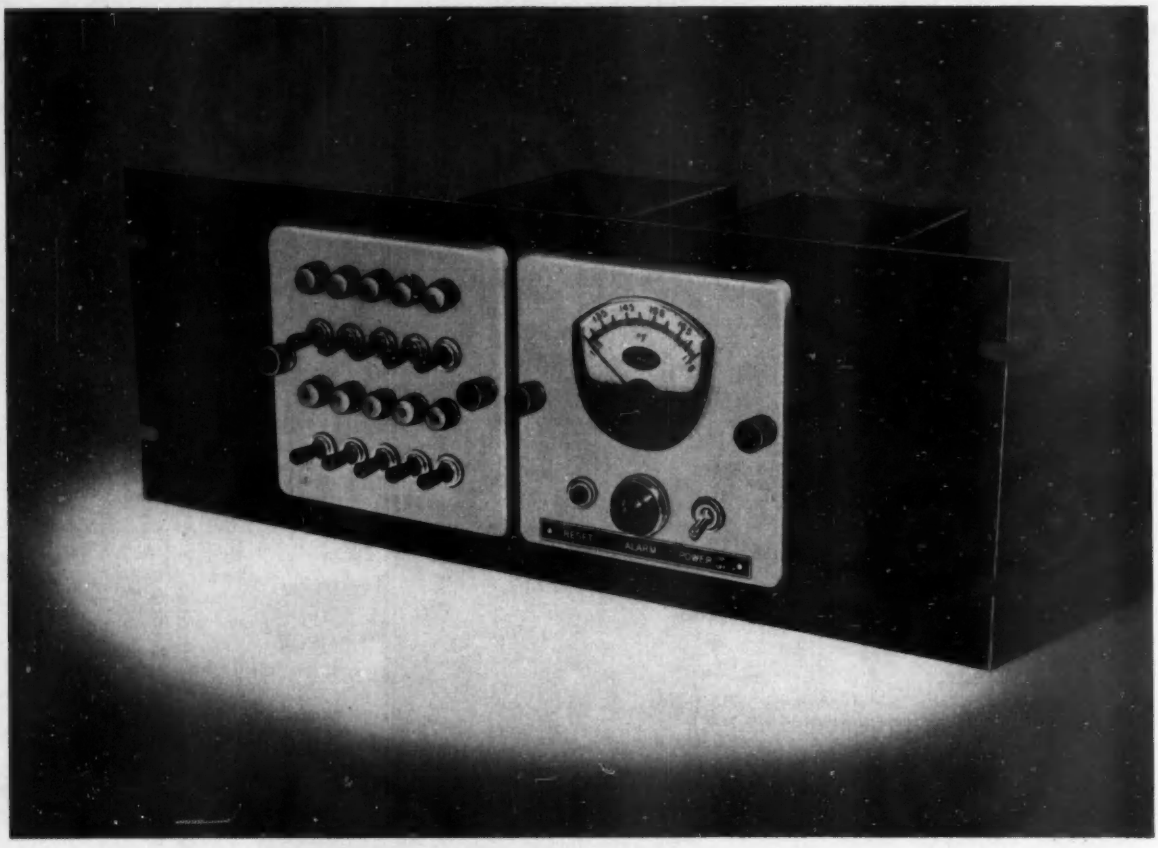
Now there's a monitor that continuously and simultaneously senses all ten of its temperature points. No scanning required . . . no delay in signalling "off" temperatures. *Ten to one it's the positive, fast-acting protection you've needed!*

Monitor's solid-state components are simple, accurate and reliable. Fenwal thermistor sensors install economically with uncompensated electric wiring, have practically limitless life. They change resistance sharply when temperatures change, send strong electrical signals to a rugged, transistorized amplifier. *Wear-free, non-moving parts that combine high performance with low maintenance!*

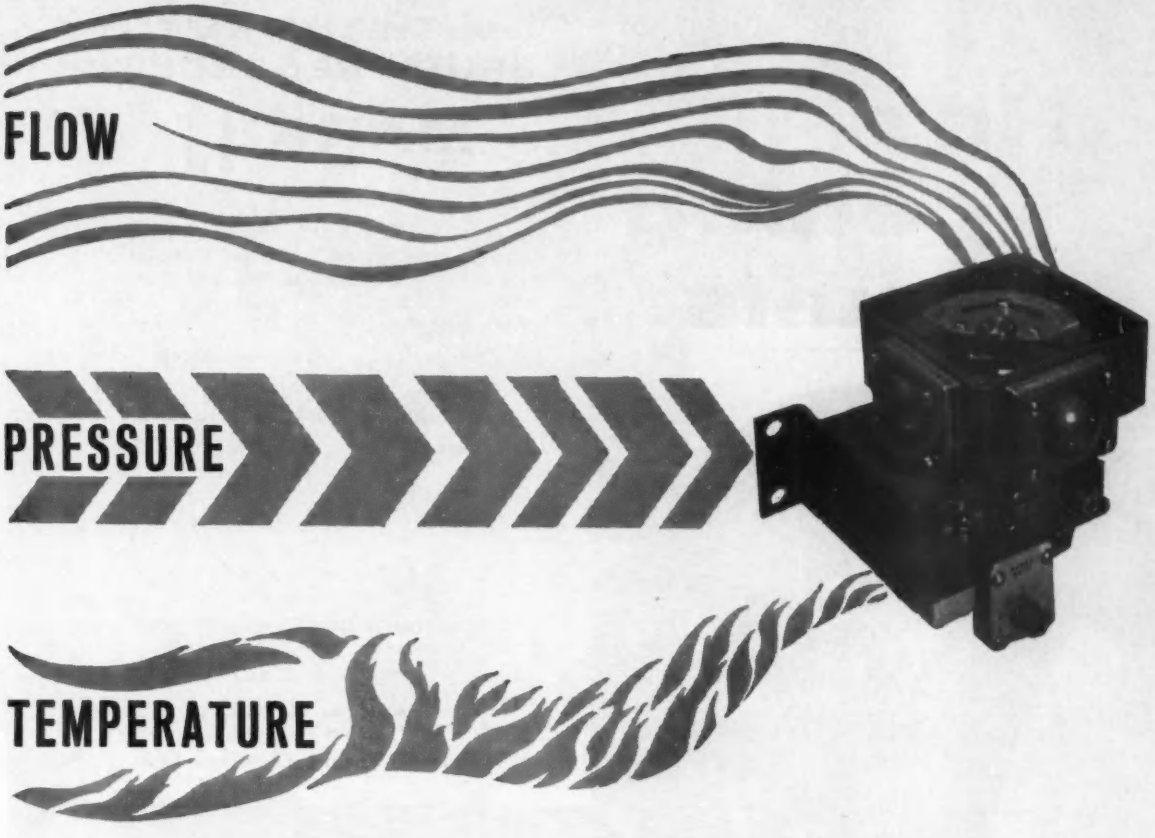
Fenwal Simultaneous Monitoring Systems are produced by a company with highly integrated design and manufacturing facilities, including its own source of thermistors. And they're repeatedly proving this "better engineering" in all the new commercial jets and many military aircraft. *Small wonder they're dependable on the toughest industrial assignments!*

For complete details or complete engineering of your specific temperature monitoring problem, contact a Fenwal Sales Engineer and write for Catalog. Fenwal Incorporated, 295 Pleasant Street, Ashland, Mass.

Fenwal Continuous 10-point Monitor indicates one or more "off" temperatures by red light or other signal. Operator merely flicks toggle switches to locate trouble. Dial shows each temperature. Temperature Range: 100°F ranges from −25 to 600°F. Voltage rating: 115/230 VAC.




ANOTHER EXAMPLE OF HOW **Fenwal** CONTROLS TEMPERATURE . . . PRECISELY




# Control Any Process Variable

*with a system based on*

*REPUBLIC'S NEW TYPE "VC" PNEUMATIC CONTROLLER*

Here is an all purpose null-balance-vector controller for use with any pneumatic transmitter. Its proportional band ranges from 2% to 500% *without changing parts*, for quick adaptation to changes in process requirements. Especially important in high-precision control, Republic's Type VC has exceptional sensitivity and a narrow dead band (less than 0.05%). Its high capacity non-bleed pneumatic amplifier consumes little air, keeps output ample. A selector block permits reverse or direct action. Local or remote pneumatic set point optional.

Companion instruments—using an identical null-balance-vector "heart"—include differential pressure, temperature and pressure transmitters . . . ratio, totalizing, multiplying, squaring and square - root - extracting relays. Many parts are interchangeable among the instruments in this "family". Besides reducing spare parts inventory, the similarity of components simplifies the task of training personnel.

Let a Republic engineer show you how these instruments can help to achieve accurate, efficient, dependable control systems. Republic Sales Offices are located in principal cities throughout the U.S.A. and Canada.

**REPUBLIC**
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2240 DIVERSEY PARKWAY CHICAGO 47, ILLINOIS
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Manufacturers of electronic and pneumatic instrument and control systems for utility, process and industrial applications.

CIRCLE 66 ON READER-SERVICE CARD

# He's getting results...

## WITH THE NEW BRUSH RECORDER MARK II

So can you. The versatile Mark II is an integrated oscillograph package—a readout tool for engineers and technicians everywhere . . . in the shop . . . in the lab . . . or in the field.

*Just plug it in . . . put it to writing . . . anywhere.*

**PERFORMANCE SPECIFICATIONS**

*Recordings*—Uniform, crisp, easily reproduced. Trouble-free ink writing on precision chart paper.

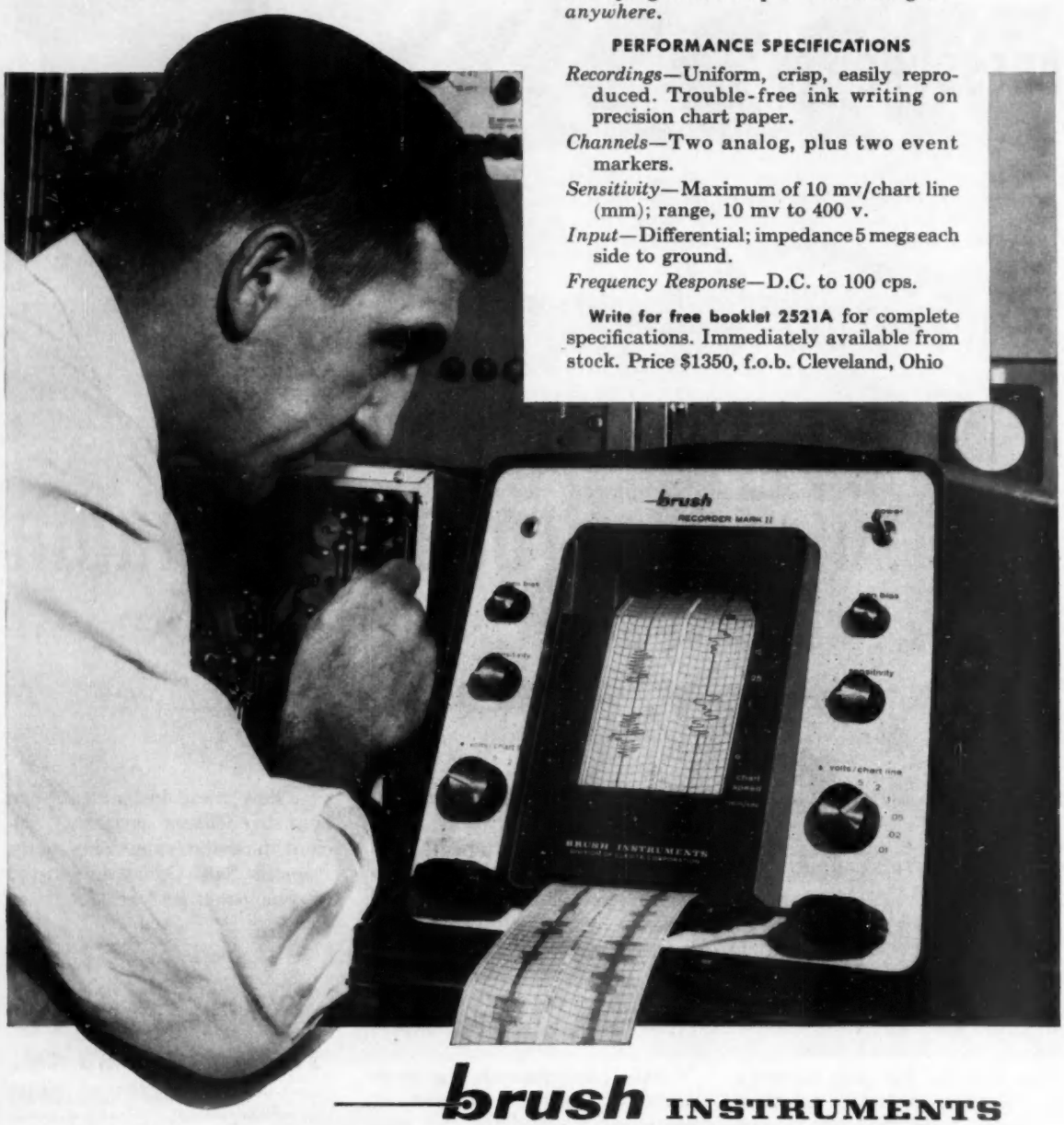
*Channels*—Two analog, plus two event markers.

*Sensitivity*—Maximum of 10 mv/chart line (mm); range, 10 mv to 400 v.

*Input*—Differential; impedance 5 megs each side to ground.

*Frequency Response*—D.C. to 100 cps.

**Write for free booklet 2521A** for complete specifications. Immediately available from stock. Price $1350, f.o.b. Cleveland, Ohio




**brush INSTRUMENTS**
DIVISION OF
37TH AND PERKINS — CLEVITE CORPORATION — CLEVELAND 14, OHIO

THOMAS A.

# EDISON

## omniguard systems protect equipment, decrease downtime in generating plants

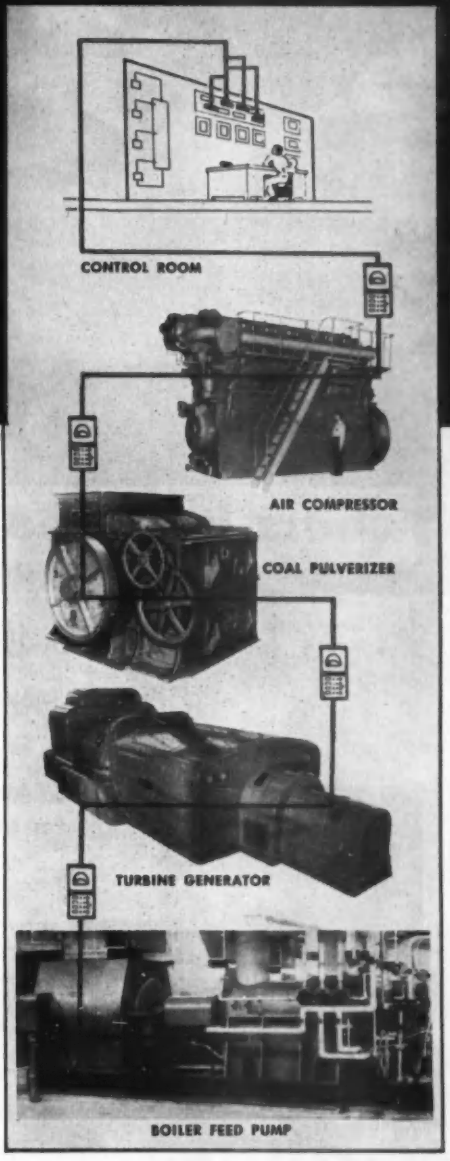
The Edison Omniguard system keeps constant watch on critical temperatures throughout electric generating plants. Omniguard monitors such vital temperatures as those of bearings on the main turbine generator, fluid drives, coal pulverizers, main feed pumps and other vital auxiliaries.

When overheating occurs the alarm sounds *before* damage occurs and corrective action may be taken immediately.

By guarding against overheating the equipment runs at optimum efficiency, lasts longer and requires less maintenance.

This modern Edison system is a simple, reliable means of keeping equipment operating at full efficiency and protecting against emergency shutdown.

For additional information on Edison Model 310 Omniguard temperature monitor and the wide variety of detectors available for use on all types of auxiliaries, pressure vessels, tanks and pipe lines, write for publication 3036C.

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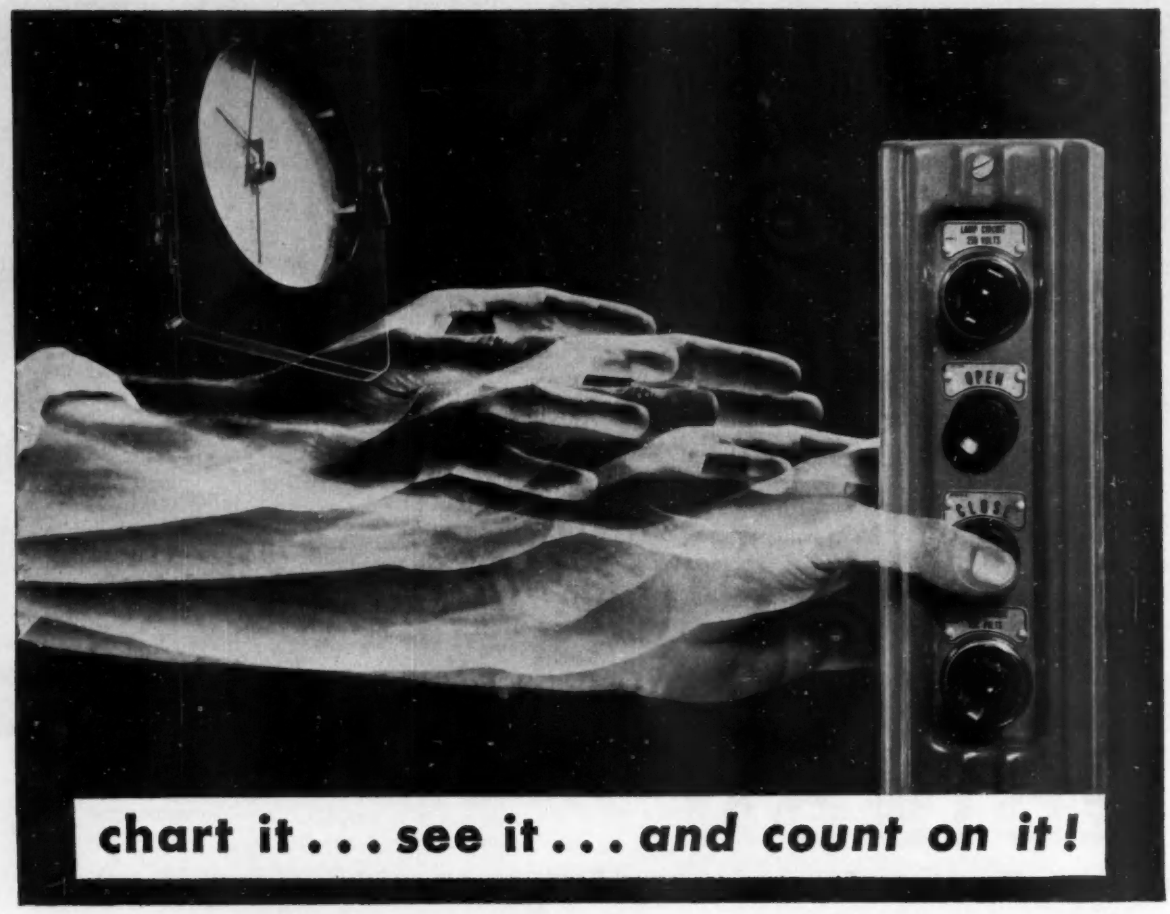


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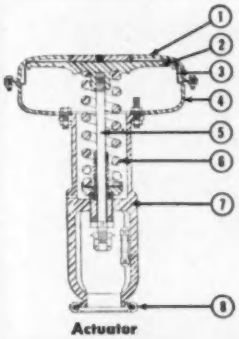
# THESE FEATURES

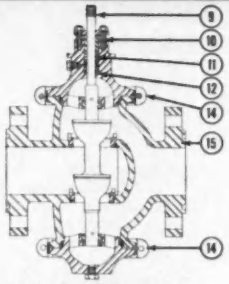
## Make The BS&B Super 70

## TODAY'S OUTSTANDING VALVE IN ITS CLASS!

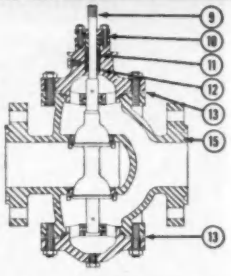
BS&B Super 70 Control Valves are widely used with instruments to control pressures, temperatures, liquid levels and flow. They efficiently handle gas, air, vapor, steam or liquids in a wide variety of applications. Valve bodies are available with either the patented clamp ring —float ring closures—up to 600# ASA— or the conventional flanged-gasketed type closures in ratings up to 2500# ASA.



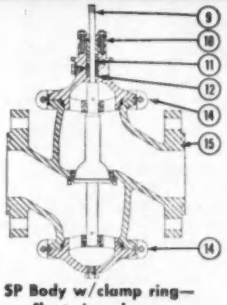
Actuator



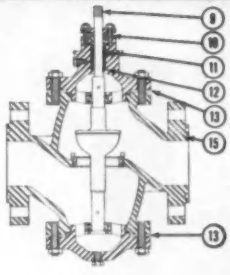
DP Body w/clamp ring—float ring closure



DP Body w/flanged-gasketed closure



SP Body w/clamp ring—float ring closure



SP Body w/flanged-gasketed closure

**VALVE BODIES AND INNER VALVES REVERSIBLE WITHOUT ADDITIONAL PARTS**

1. Direct, Reverse and Pressure Balanced Actuator
2. Diaphragm Plate of Ductile Iron
3. Moulded Diaphragm of Buna-N With Nylon Inserts
4. Pressed Carbon Steel Case
5. AISI 303 Stainless Steel Stem
6. Tempered Steel Spring, Precision Calibrated To Within ± 2%
7. Ductile Iron Yoke
8. 2-Piece Forged Steel Clamp Ring
9. Type 303 Stainless Steel Packing Follower
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CIRCLE 70 ON READER-SERVICE CARD

# BASIC BUILDING BLOCKS

## SERVO SYSTEM COMPONENTS

- Servo Motors—Frame Sizes 5-25
- Synchros and Resolvers—Frame Sizes 5-25
- Tachometers—Damping, Rate, Integrating
- Transistorized Amplifiers—High Temperature 2.5-16 watts

Synchros—Size 25—20 sec. max. error

## HYDRAULICS

6100 Series Servo Valve

***Servo Valves***

- Two moving parts
- Anti-clogging — over size orifices, high pressure clearing
- Flow rates—0-5, 0-10 gpm

***Systems***

For hi-performance hydraulic or pneumatic missile control.

## COMPUTERS

Navigational Computer

- Great Circle Course and Navigational
- Inertial Position
- Guidance
- Analog and Digital for Missile Applications

## INERTIAL GUIDANCE

25 lb. Inertial Platform

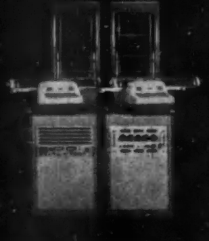
Components include floated gyros, single and two-axis accelerometers, first and second integrators, computers. Complete systems in production for major missile applications feature high accuracy, long-term reliability, light-weight construction.

## GYROS

Miniature Floated Gyro

- Rate-floated Integrating; Spring Restrained
- Vertical—Miniature, Self-Contained
- Two Axis Free For Missile Control
- Directional, Conventional and Roll Stabilized
- 3 Gyro, 3 and 4 Gimbal Platforms
- North Seeking Theodolites

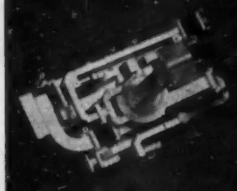
## GROUND SUPPORT



Digital Logging System

Completely integrated ground support equipment based on unique Kearfott test equipment modules for analog or digital, manual, semi-automatic or fully automatic testing of components, sub-systems or systems.

## MICROWAVE



Antenna Array

- Waveguides, Strip Transmission Lines, Ferrite Components
- Radar rf and Antenna Assemblies
- Transponder Systems, Target Simulators, Test Sets
- Traveling Wave Assemblies

***Engineers:***

**Kearfott offers challenging opportunities in advanced component and system development**

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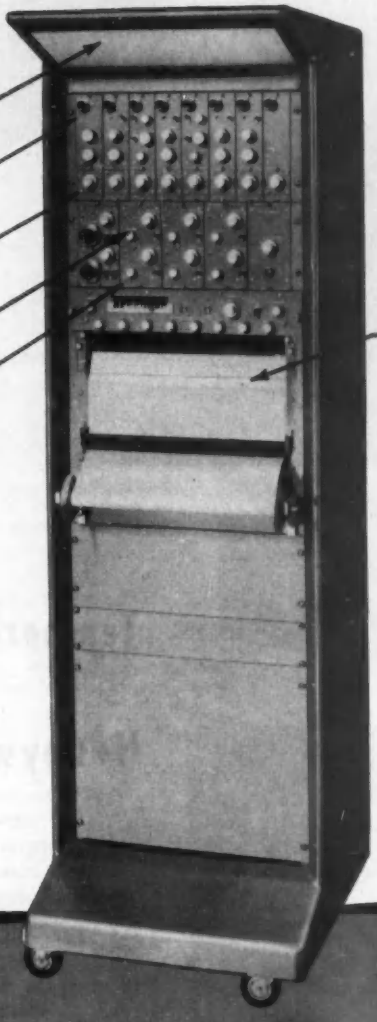
ALL TRANSISTOR

# TYPE R DYNOGRAPH

*the most versatile . . . most sensitive direct writing unit available*



Illuminated canopy

Type 9800 series input couplers provide all input, control and balance functions. Input available both front and rear.

Type 481 Preamplifier provides sensitivities from one microvolt to 5 volts per mm.

Type 482 power amplifiers—may be used without preamplifiers for up to 10 mv/cm sensitivity

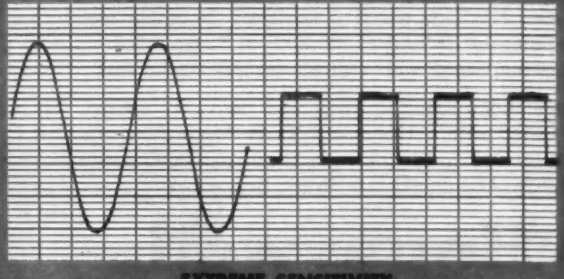
Zero suppression control

504-A paper drive—speeds from 1 to 250 mm/sec. Electrical speed shift 1 to 250 mm per minute available. Zero weave high precision drive, 850 ft. capacity (heat or electric) 1500 ft. (ink). Front loading, with full unobstructed record visible from front.

## *Combining all these features...*

- *stable d-c sensitivity of one microvolt per mm*
- *true differential input*
- *high input impedance*
- *response to beyond 150 cps.*
- *reluctance, differential transformer, strain gage with a-c or d-c excitation, thermocouples, etc., used with all preamplifiers*
- *deflection time less than 1.5 milliseconds (2.5 ms with preamplifiers)*
- *fixed precision calibration*
- *instant warm-up*
- *precision source for d-c and 400 cycle excitation, self-contained*
- *zero suppression, twenty times full scale, both directions*

**FULL SCALE, UNRETOUCHED CHARTS PRODUCED ON THE TYPE R DYNOGRAPH**



**EXTREME SENSITIVITY**

**10 Microvolt RMS Sine Wave** — **Ten Microvolt D-C Square Wave**

*Four recording media. Heat or electric rectilinear—ink or electric curvilinear. Readily convertible.*

**All these features . . . plus 8 channels in only 35″ of rack space.** Whatever your application for direct writing records . . . you should investigate the ability of the Offner Type R Dynograph to do the job *better* and more *simply*. Using transistor circuits* developed and tested for over three years in thousands of channels of Offner equipment, the Type R Dynograph has already proved its superiority in practically every respect to *any other* direct writing oscillograph. Write on your company letterhead for literature giving details and specifications.

**Patents granted and pending*

**OFFNER ELECTRONICS INC.**
3904 River Road, Schiller Park, Ill.
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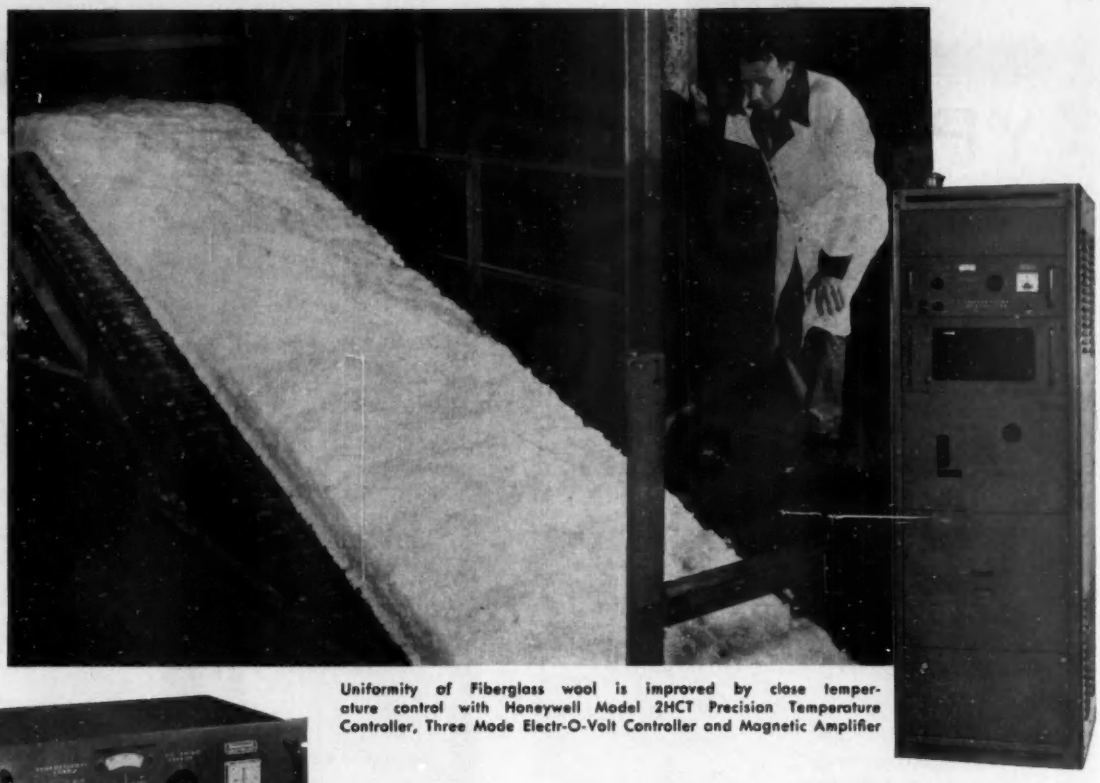


Uniformity of Fiberglass wool is improved by close temperature control with Honeywell Model 2HCT Precision Temperature Controller, Three Mode Electr-O-Volt Controller and Magnetic Amplifier

Model 2HCT-2, single range control unit with direct reading analog dial, is available in a wide variety of ranges for any millivoltage or thermocouple input.

# Temperature Control within 0.05% with new Honeywell Temperature Controller

The new Honeywell Precision Temperature Controller, series 2HCT, operates magnetic amplifiers and similar devices for control of saturable core reactor furnaces whose temperature can be measured with thermocouples.

The 2HCT consists of a null balance input circuit with manually adjusted set points and a highly stable d-c amplifier. The difference between the thermocouple signal and the set point is amplified 100,000 times to operate control circuits. Proportional band adjustment permits a decrease of sensitivity by a factor of 10.

There are 2 standard models: The 2HCT-2, which is shown above at left, and the 2HCT-3, which is designed for noble metal couples, covering temperatures from 0 to 3,000°F in 3 steps. Setting to ½ part in 3,000 is accomplished with a direct reading digital dial.

For applications requiring reset and derivative control functions, the 2HCT is used with a Honeywell Three Mode Electr-O-Volt Controller. Write for 2HCT Specification Sheet to Minneapolis-Honeywell, Dept. 34, Boston Division, 40 Life Street, Boston, Mass.

- No moving parts . . . magnetic converter input
- No stray electrical pickup . . . 60 cycle rejection of greater than $6 \times 10^9$
- Continuous automatic standardization
- Sensitive to change of less than 1 μv
- Full output power for 12 μv input deviation from set point
- Three-mode control available using Honeywell Electr-O-Volt

**Honeywell**

First in Control

# NOW... *high performance magnetic amplifiers* at LOW COST!

## *New 1290 Series* VICKERS® *Super Power Magnetic Amplifier*
## *...price is as little as one-half that of units previously available*

18 STANDARD UNITS—515 VA TO 32.5 KVA OUTPUT POWER

| REACTOR BULLETIN NUMBER | A-C SUPPLY VOLTS | A-C SUPPLY PH | [1]DC CONTROL A-T | $C_T$ | %CONTROL FACTOR | %D-C OUTPUT RATINGS V-A | VOLTS | AMPS | LOAD RES. (OHMS) | [3]3-CYCLE CONTROL WATTS | RECTIFIERS SATURATING QTY | SATURATING CODE NO. | COMPLEMENTARY QTY | COMPLEMENTARY CODE NO. | [4] 1, 1 ½ A-C OUTPUT RATINGS V-A | VOLTS | AMPS | LOAD RES. (OHMS) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1296-515 | 120 | 1 | 15 | .016 | 0.73 | 515 | 77 | 6.7 | 11.5 | 1.5 | 1 | VM2GVW1JA | 2 | VM3GVW1JA | 825 | 96 | 8.4 | 11.7 |
| 1296-800 | 120 | 1 | 19 | .012 | 0.95 | 800 | 77 | 10.4 | 7.4 | 1.9 | 1 | VM2HVW1JA | 2 | VM3HVW1JA | 1280 | 99 | 13.0 | 7.6 |
| 1296-1360 | 120 | 1 | 15 | .033 | 1.70 | 1365 | 78 | 17.5 | 4.4 | 2.3 | 1 | VM2NVW1JA | 2 | VM3NVW1JA | 2210 | 100 | 22.1 | 4.5 |
| 1296-1680 | 120 | 1 | 17 | .033 | 1.90 | 1680 | 78 | 21.6 | 3.6 | 3.8 | 1 | VM2NVW1JA | 2 | VM3NVW1JA | 2710 | 100 | 27.1 | 3.7 |
| 1296-2510 | 240 | 1 | 18 | .029 | 2.1 | 2510 | 157 | 16.0 | 9.8 | 4.2 | 1 | VM4NVW1JA | 2 | VM6NVW1JA | 4060 | 201 | 20.2 | 10.0 |
| 1296-3160 | 240 | 1 | 19 | .042 | 3.1 | 3160 | 158 | 20.0 | 7.9 | 5.2 | 1 | VM4NVW1JA | 2 | VM6NVW1JA | 5100 | 202 | 25.2 | 8.0 |
| 1296-4350 | 240 | 1 | 24 | .035 | 3.8 | 4350 | 159 | 27.4 | 5.8 | 7.5 | 1 | VM4JVW2JA | 4† | VM6JVW1JA | 6940 | 203 | 34.2 | 5.9 |
| 1296-6120 | 240 | 1 | 25 | .050 | 6.3 | 6120 | 160 | 38.3 | 4.2 | 12.5 | 1 | VM4NVW2JA | 4† | VM6NVW1JA | 9800 | 204 | 48.0 | 4.3 |
| 1296-7860 | 240 | 1 | 30 | .043 | 7.4 | 7860 | 160 | 49.0 | 3.3 | 14.7 | 1 | VM4KVW2JA | 4† | VM6KVW1JA | 12600 | 204 | 62.0 | 3.3 |
| 1296-2140 | 240 | 3 | 18 | .013 | 0.85 | 2140 | 198 | 10.8 | 18.3 | 1.7 | 3 | VD8GVW1JA | | | | | | |
| 1296-3320 | 240 | 3 | 22 | .011 | 1.10 | 3320 | 200 | 16.6 | 12.1 | 2.2 | 3 | VD8HVW1JA | | | | | | |
| 1296-5710 | 240 | 3 | 16 | .033 | 2.20 | 5710 | 202 | 28.3 | 7.1 | 4.3 | 3 | VD8NVW1JA | | | | | | |
| 1296-6830 | 240 | 3 | 20 | .029 | 2.4 | 6830 | 203 | 33.6 | 6.0 | 4.7 | 3 | VD8NVW1JA | | | | | | |
| 1296-10800 | 480 | 3 | 22 | .025 | 2.5 | 10800 | 408 | 26.4 | 15.5 | 4.9 | 6 | VH16NVW1JA | | | | | | |
| 1296-13300 | 480 | 3 | 22 | .037 | 3.6 | 13300 | 410 | 32.4 | 12.7 | 7.1 | 6 | VH16NVW1JA | | | | | | |
| 1296-18600 | 480 | 3 | 28 | .029 | 4.6 | 18650 | 411 | 45.4 | 9.1 | 9.1 | 12† | VH16JVW1JA | | | | | | |
| 1296-25500 | 480 | 3 | 29 | .041 | 7.0 | 25500 | 412 | 62.0 | 6.7 | 13.8 | 12† | VH16NVW1JA | | | | | | |
| 1296-32500 | 480 | 3 | 34 | .035 | 8.2 | 32500 | 412 | 79.0 | 5.2 | 16.3 | 18† | VH16NVW1JA | | | | | | |

1. *Ampere-turns required to control a typical unit.*
2. *Permits calculation of linear control power for any time constant.*
3. *All reactor ratings based on class "B" operation.*
4. *For full control (15:1 range).*

*(Complete notes contained in Bulletin 1296-5.)*

■ **LOW COST**—most watts per dollar.

■ **GAPLESS CORES**—permit minimum control ampere-turns; eliminate irregular performance introduced by air gaps.

■ **ENGINEERING ASSISTANCE**—at Vickers Sales Engineering Offices listed below.

■ **FOUR WEEK DELIVERY**

Vickers, the pioneer in magnetic amplifier development, with more than 1,000,000 man-hours of direct experience in the design and application of magnetic amplifiers, now brings you a new line of higher power units... the "Super Power". 1290 Series. The new design of these tapewound, gapless core amplifiers coupled with superior production techniques provides Vickers 1290 Series Amplifiers with higher performance and operating efficiency... you get more output watts per dollar. Write today for complete details.

EPA 1290-S

*Send for Bulletin 1296-5*

ELECTRIC PRODUCTS DIVISION — VICKERS

**VICKERS INCORPORATED**
DIVISION OF SPERRY RAND CORPORATION
**ELECTRIC PRODUCTS DIVISION**
1805 LOCUST STREET • SAINT LOUIS 3, MISSOURI

***Central Office:*** **St. Louis**
***Sales Engineering Offices:*** **Chicago, Cleveland, Detroit, Los Angeles, New York, Washington, D. C.**

**CIRCLE 74 ON READER-SERVICE CARD**

# NEW!

## SMALL!

# DELCO POWER TRANSISTOR

*Designed for use where space and weight are restricting factors*

| MAXIMUM RATINGS | 2N1172 |
|---|---|
| Collector Diode Voltage | 40 volts |
| Emitter Diode Voltage | 20 volts |
| Collector Current | 1.5 Amperes |
| Junction Temperature | 95°C |
| **TYPICAL CHARACTERISTICS (25°C)** | |
| Typ. Collector Diode Current $I_{co}$ $V_{cb}$=40 volts | 50$\mu$ |
| Current Gain ($V_{cc}$= −2 volts, $I_c$=100 Ma) | 70 |
| Current Gain ($V_{cc}$= −2 volts, $I_c$=½A) | 30 |
| Saturation Resistance | 0.3 ohms |
| Cutoff Frequency (Common Emitter) | 17 kc |
| Thermal Resistance | 12° C/Watt |

The 2N1172 is a medium power transistor offering dependable operation in a new range of applications where space and weight have been a problem.

It's a mighty mite with more punch in a smaller package. The 2N1172, excellent for output use or as a driver for a very high power transistor, has already proved especially effective in DC amplifiers, voltage regulators, and as a driver for a high power stage in servo or other amplifiers.

This PNP germanium transistor is housed in a modified version of the JEDEC 30 package with a diamond shaped base for improved thermal conduction. It dissipates up to 2 watts at a mounting base temperature of 70 degrees centigrade. Available now in volume production—write today for complete engineering data.

## DELCO RADIO

**Division of General Motors**
**Kokomo, Indiana**

BRANCH OFFICES

Newark, New Jersey
1180 Raymond Boulevard
Tel: Mitchell 2-6165

Santa Monica, California
726 Santa Monica Boulevard
Tel: Exbrook 3-1465

# KOLLMORGEN Instruments and Systems for underwater viewing

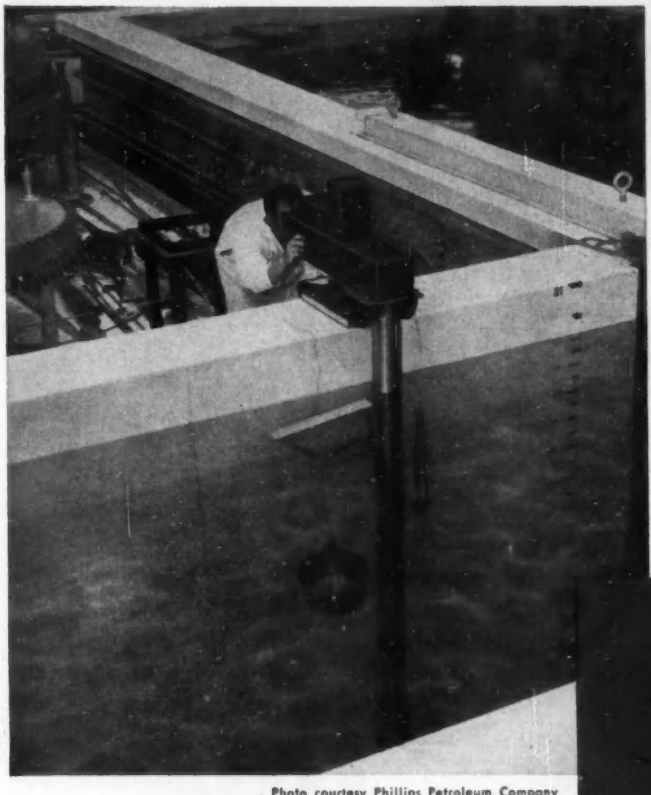


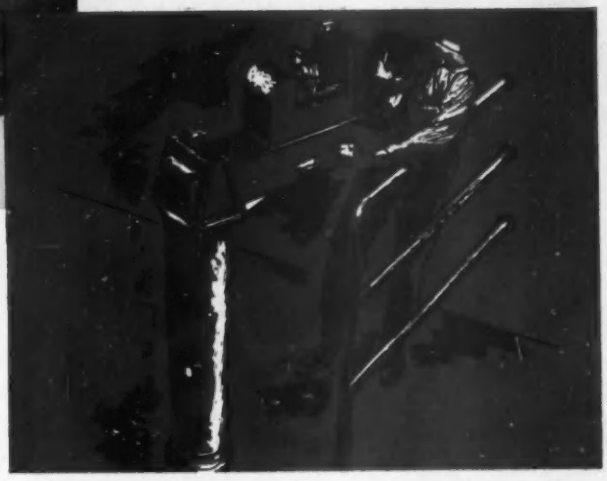
Photo courtesy Phillips Petroleum Company

At the National Reactor Testing Station, a Phillips Petroleum Company technician inspects radioactive materials through a Kollmorgen Underwater Periscope. The instrument is mounted on the edge of the working canal which abuts the Engineering Test Reactor.

Kollmorgen designs and manufactures optical, mechanical and electronic instruments and systems for remote viewing, inspection, testing and photography. The machine tool, chemical process, atomic energy, missile, oil and pipe line, electronic and motion picture industries exemplify the variety of fields which Kollmorgen serves.

If you face a remote viewing problem it may be that a standard Kollmorgen instrument can help solve it. If not, our engineering department can design a special instrument to meet your needs. A procurement sketch with brief description of the problem is sufficient to start.

A new twenty-four page illustrated brochure describes our facilities and products. You may have a copy by writing Dept. 215.

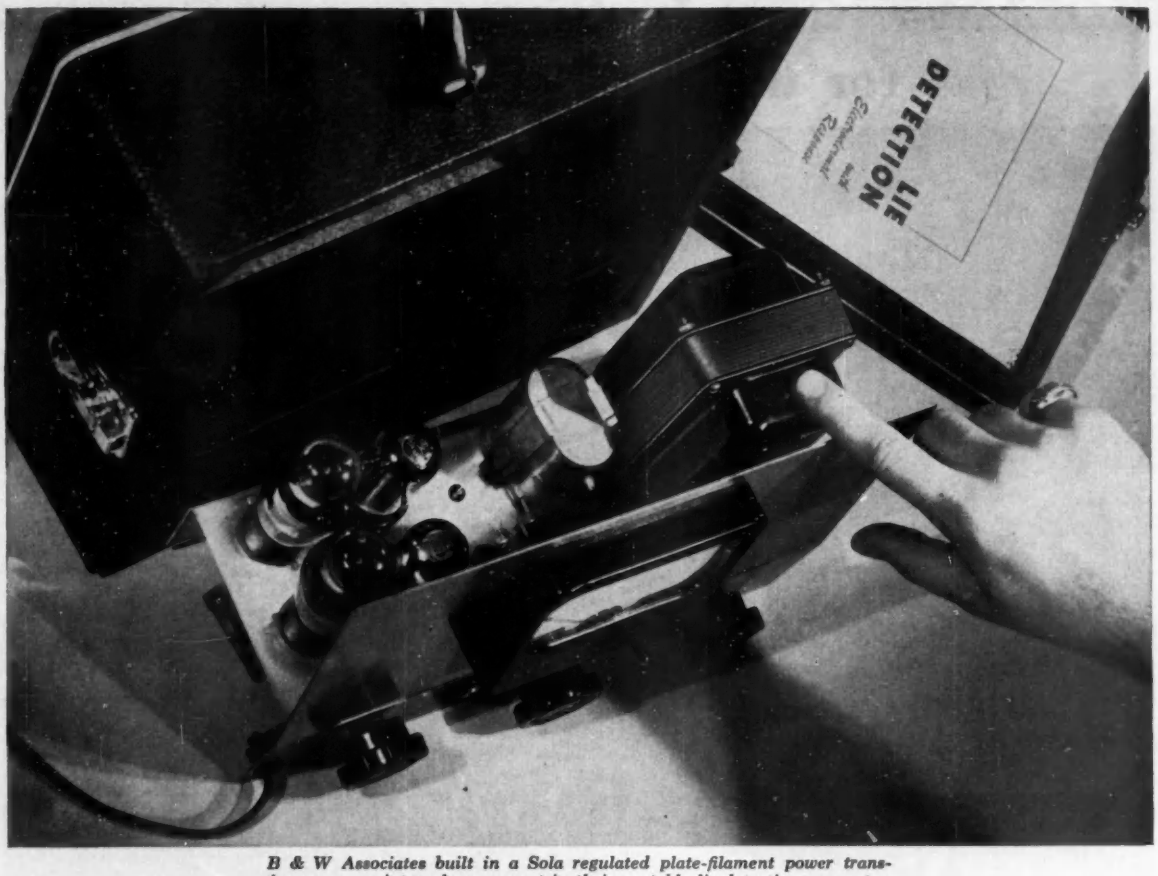


Most major atomic installations use Kollmorgen Remote Viewing Equipment. At the Shippingport Reactor, a Kollmorgen Periscope similar to the one shown (right) is used for inspecting fuel elements. The instrument is equipped for photography of radioactive material.

## for internal inspection

Zeiss-Kollmorgen Borescopes are versatile devices for the internal inspection of tubing, long bores, engines, aircraft structures, etc. They are self-illuminating. Diameters from .100", lengths to 45 feet or longer.

KOLLMORGEN
optical corporation
NORTHAMPTON, MASSACHUSETTS




*B & W Associates built in a Sola regulated plate-filament power transformer as an integral component in their portable lie-detection apparatus.*

# Portable lie detector operates accurately with Sola-regulated plate and filament voltages

This sensitive polygraph operates by picking up and immensely amplifying tiny electrodermal responses. It's small wonder that line voltage variations encountered in field operation must be corrected if the responses of the witness are to be measured accurately.

The lie detector's built-in power supply transformer is a Sola Constant Voltage Plate-Filament Transformer which performs this dual function: (1) it supplies plate and filament voltages just as an ordinary power supply transformer would do; (2) it regulates these supply voltages within ±3% even when the line voltage varies over a 100 to 130-volt range.

Besides providing regulation which assures accurate polygraph operation, the Sola transformer protects tubes and components from cold inrush current and from fault currents.

This simple, reliable component costs little more than ordinary, non-regulating transformers. And compared to other types of regulating circuitry used with conventional power transformers, it is considerably cheaper.

The plate-filament regulator is only one of the complete family of Sola Constant Voltage Transformers including such special types as filament and adjustable-output units. More than 40 models are available from stock, and Sola manufactures custom-designed units in production quantities to meet special needs.

***For additional information write for Bulletin 26 E-CVE***

Sola Electric Co., 4633 W. 16th St., Chicago 50, Ill., Bishop 2-1414 • Offices in principal cities • In Canada, Sola Electric (Canada) Ltd., 24 Canmotor Ave., Toronto 18, Ont.

SOLA

CONSTANT VOLTAGE TRANSFORMERS

REGULATED DC POWER SUPPLIES

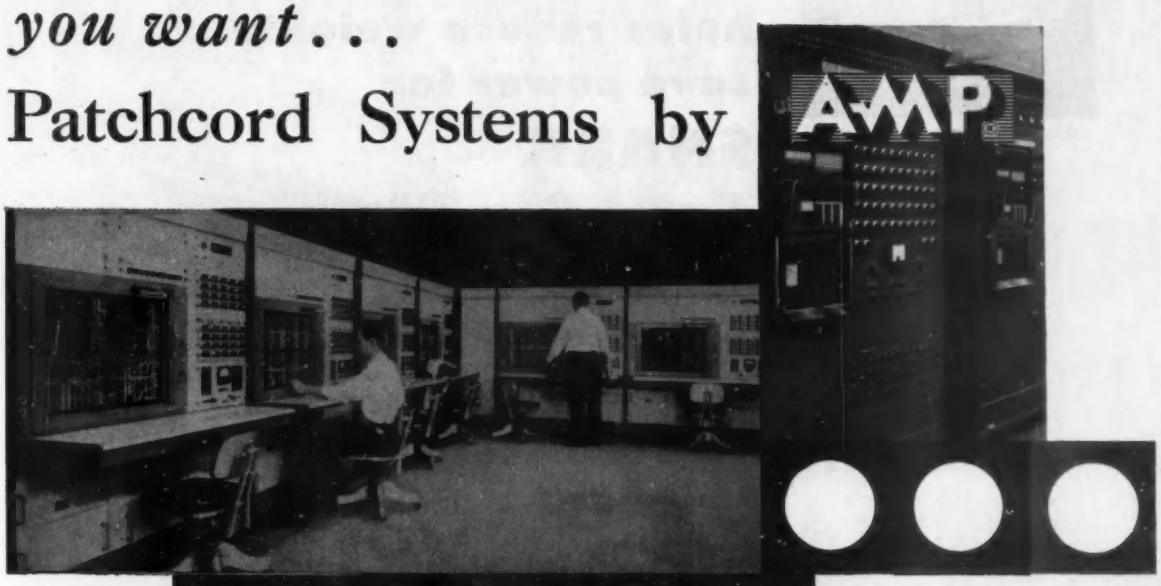
MERCURY LAMP TRANSFORMERS

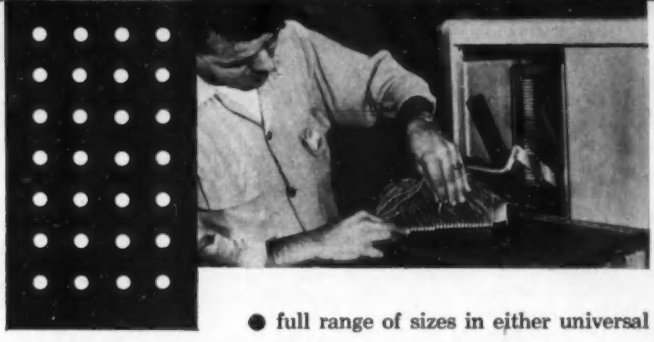
FLUORESCENT LAMP BALLASTS

A DIVISION OF BASIC PRODUCTS CORPORATION

# *for all the programming features you want...*

# Patchcord Systems by AMP





*In data processing and telemetering equipment, analog computers and other low signal level circuits, A-MP Patchcord Programming Systems and Panels offer the precise features you need, many of them exclusive. Here are a few:*

- full range of sizes in either universal or shielded types
- shielded systems feature patchcords constructed of coaxial cable and boards of unique cellular design which provide complete isolation for all signal circuits and positive grounding for all shields
- patented wiping action pre-cleans all contact surfaces whenever pre-programmed removable boards are placed in service
- frame mechanism assures positive contact when closed yet opens easily for quick board changes
- for complete data on patchcord system sizes, patchcords, and specifications on electrical characteristics (including voltage and current ratings—leakage resistance, capacitance and inductance) send for AMP's all new Programming Systems Catalog.

# AMP INCORPORATED

**GENERAL OFFICES: HARRISBURG, PENNSYLVANIA**

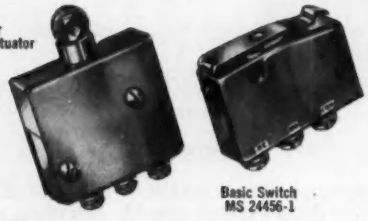
A-MP products and engineering assistance are available through subsidiary companies in: Canada • England • France • Holland • Japan

CIRCLE 78 ON READER-SERVICE CARD

Cross Section of KX4 Switch (actual size)

# KLIXON KX4 Hermetic Switch helps reduce weight, save power for SNARK

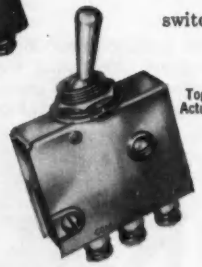
Cole Electric Substation



Roller Plunger Actuator

Basic Switch MS 24456-1

Roller Leaf Actuator



Toggle Actuator

A vital weapon in the U. S. Air Force arsenal is the Northrop SNARK, a 5,000-mile Intercontinental Guided Missile. And, in the SNARK as in other operational aircraft and guided missiles, Klixon controls play a vital role.

The switch-over problem from ground to missile power was solved by a Cole Electric Company miniaturized, electrical substation which reduces the weight from several hundred pounds to 28 pounds.

And, an important component in the Cole substation is the Klixon KX4 Hermetic Switch, manufactured to exacting tolerances, **and fully approved under MS 24456-1 (USAF).**

The KLIXON KX4 Hermetic Switch is enclosed in a strong steel case capable of withstanding heavy impact and compression loads. True hermetic sealing is achieved with a metal "wave type" diaphragm at the actuating lever, providing precision switching unaffected by all environmental conditions. The KLIXON KX4 has a 10 ampere 30V D.C. or 115V A.C. rating and is available with a variety of actuators.

We'll be pleased to design special packaging to meet the requirements of your application. Write for our precision switch catalog.

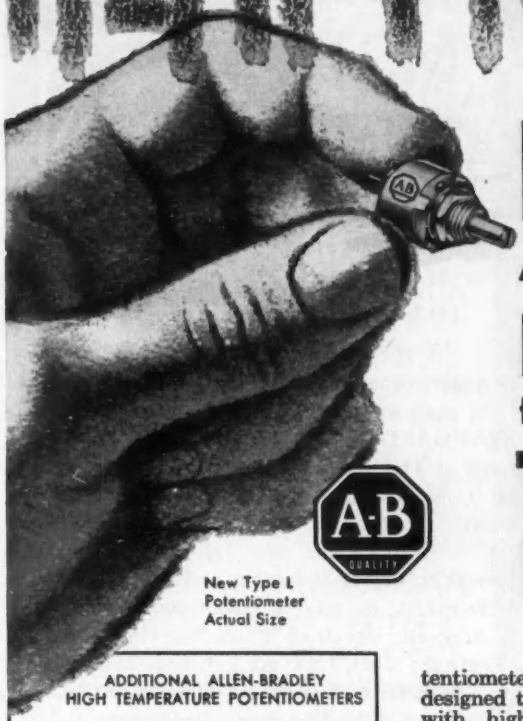
*Western manufacturers* — refer inquiries direct to Metals & Controls Corporation, Southern California Office... 232 North Lake Avenue, Pasadena, California. Telephone Ryan 1-4288.

**METALS & CONTROLS CORPORATION**

*Spencer Division* 5305 Forest Street, Attleboro, Mass.

KLIXON®

# HEAT PROBLEMS?



New Type L Potentiometer Actual Size

## NEW

**Allen-Bradley**

## POTENTIOMETERS

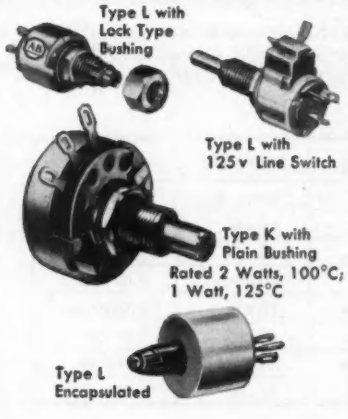
**for use in**

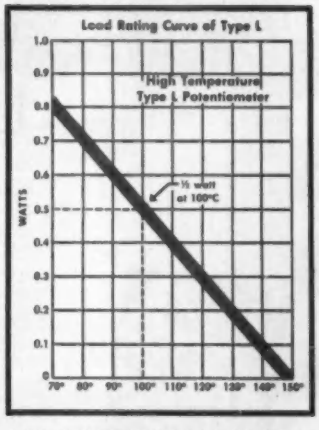
## TEMPERATURES UP TO 150°C!

This new Allen-Bradley potentiometer—the Type L—is especially designed to solve problems associated with high ambient temperatures—*and* space conservation. Although extremely compact—0.5 inch in diameter—the Type L control has a conservative rating of 0.5 watt when operating in an ambient temperature of 100°C. And, it provides reliable performance when operated at a temperature of 150°C—under "no load" conditions. (See graph at right.)

The new Type L control features the same solid, *hot molded* resistance element that has proved unequaled for long life, smooth operation, and low "noise" characteristic in Allen-Bradley's popular Type J, Type K, and Type G potentiometers. When temperature and space problems in your designs plague you, this new A-B "high temperature" potentiometer is a reliable answer. Please send for complete information, today.

ADDITIONAL ALLEN-BRADLEY HIGH TEMPERATURE POTENTIOMETERS


Type L with Lock Type Bushing
Type L with 125 v Line Switch
Type K with Plain Bushing
Rated 2 Watts, 100°C; 1 Watt, 125°C
Type L Encapsulated




AMBIENT TEMPERATURE °C.

**Load Capabilities of Type L below the Critical Resistance Value. Type L Far Exceeds the Requirements of MIL-R-94B.**

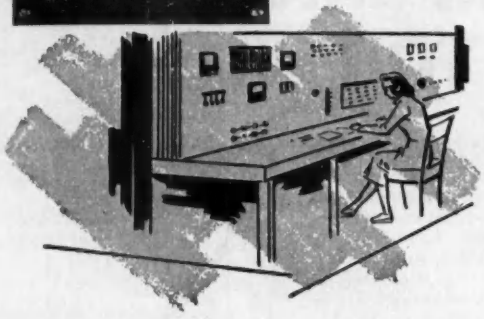
# ALLEN-BRADLEY

## Quality Electronic Components

*Allen-Bradley Co., 210 W. Greenfield Ave., Milwaukee 4, Wis. • In Canada: Allen-Bradley Canada Ltd., Galt, Ont.*

CIRCLE 80 ON READER-SERVICE CARD

# STANDARD ...SYNONYM for PRECISION in TIMING



For timing requirements in research, testing or production . . . if the need for *precision* is paramount . . . the choice is STANDARD.

Recognized as THE criterion by which other timers are judged (and *calibrated*), STANDARD Elapsed Time Indicators are noted for their long life under continuous use.

Large enough to work with handily and read readily, STANDARD timers are electric clutch controlled by manual or automatic switch or by electric circuits or output of electronic tubes. Units are synchronous motor driven . . . available for flush panel mounting or portable use . . . equipped for manual or electric zero reset.

*For ultra precision timing with AC current, models available for 400 CPS operation. Also available: 400 CPS power supply operating from DC source.*

| MODEL | SCALE DIVISIONS | TOTALIZES | ACCURACY |
|---|---|---|---|
| S-100 | 1/5 sec. | 6000 sec. | ±.1 sec. |
| S-60 | 1/5 sec. | 60 min. | ±.1 sec. |
| SM-60 | 1/100 min. | 60 min. | ±.002 min. |
| S-10 | 1/10 sec. | 1000 sec. | ±.02 sec. |
| S-6 | 1/1000 min. | 10 min. | ±.0002 min. |
| S-1 | 1/100 sec. | 60 sec. | ±.01 sec. |
| MST | 1/1000 sec. | .360 sec. | ±.001 sec. |
| MST-500 | 1/1000 sec. | 30 sec. | ±.002 sec. |

Request descriptive Catalog No. 198

**THE STANDARD ELECTRIC TIME COMPANY** | 89 LOGAN STREET SPRINGFIELD, MASSACHUSETTS

*Travelling Display*— Watch for showing in your area. See complete STANDARD Systems in operation.

*ALSO MANUFACTURERS OF:*

Emergency Lighting Equipment

Laboratory Panels

Hospital Signalling Equipment

Analogue Computers

Precision Timers

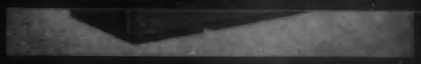
# S-C 4020 HIGH-SPEED MICROFILM PRINTERS

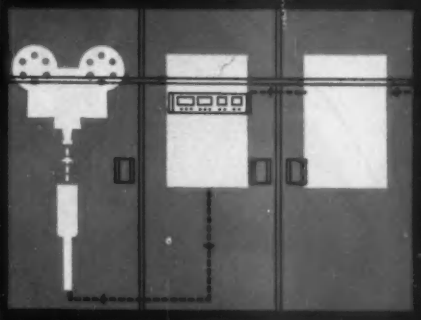
Capable of printing characters and plotting points at the rate of 15,000 per second, the S-C 4020 is equally adaptable to commercial and scientific applications where high-speed microfilming is required. This versatile new printer is compatible with most high-speed data processing systems used throughout business, government and industry . . . and is capable of both on-line and off-line cperation. The S-C 4020 has resulted from experience gained by Stromberg-Carlson in the development, manufacture and field testing of other microfilm printers in the S-C 4000 Series, including the S-C 4000, custom-developed for use with the Livermore Automatic Research Computer (LARC), and the S-C 4010, now used in conjunction with the Naval Ordnance Research Calculator (NORC).

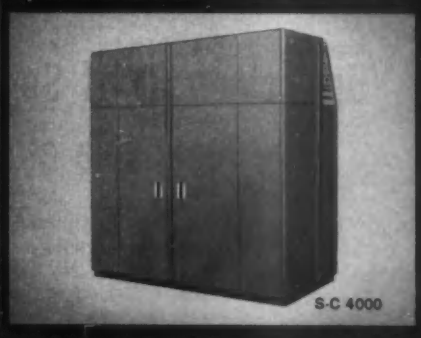
Send for complete information concerning the S-C 4020 High-Speed Microfilm Printer. Ask for Bulletin 5-C. Write today: Stromberg-Carlson - San Diego, 1895 Hancock Street, San Diego 12, California.

**GENERAL DYNAMICS**
STROMBERG-CARLSON DIVISION

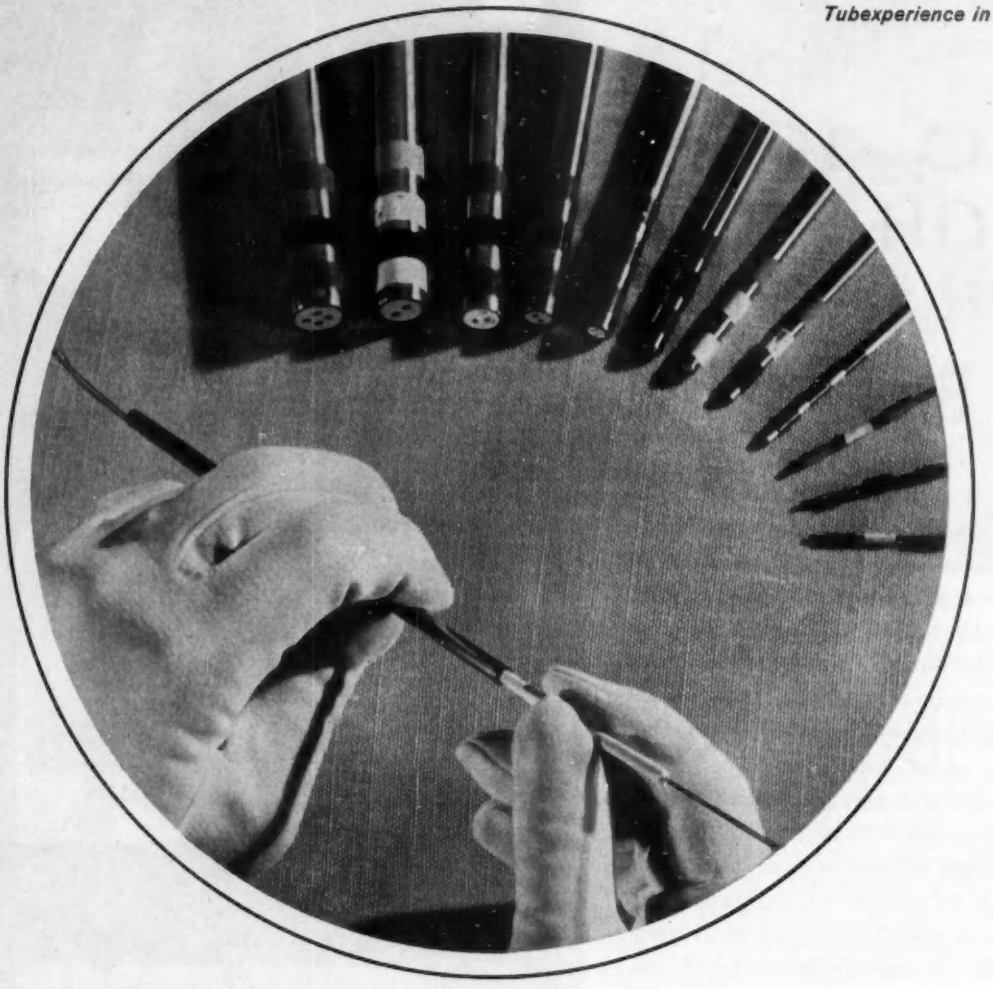
CIRCLE 82 ON READER-SERVICE CARD







*Tubexperience in action*



# How clean ID of Superior tubing helped increase thermocouple electrical resistivity ratings

Tubing with unusually clean, smooth ID and produced to very close tolerances is a prime requisite for sheathing cerâmic-pack thermocouples. Any irregularities will destroy the effectiveness of the finished product in protecting equipment and processes which it serves.

E. C. Smith Manufacturing Co., Conshohocken, Pa., relies on Superior to supply the tubing it needs to meet high-quality standards. The tubing ranges widely in sizes and analyses and includes many types of stainless steel in the 300 and 400 Series, Hastelloy,[1] Nichrome V,[2] "A" Nickel,[3] Inconel,[3] Monel,[3] 30% Cupro Nickel, and titanium. How well Superior tubing satisfies requirements is indicated by resistivity tests recently made. Thermocouples sheathed with Superior tubing were found to have electrical resistivity ratings that exceeded published standards by 1,000,000 megohms.

Superior's long experience in producing small tubing to meet rigid specifications in a broad range of analyses, sizes and shapes helped E. C. Smith Manufacturing Co. improve its product. It is doing the same for manufacturers in many different industries. For detailed information on this tubing and the ability of Superior to help you, write for a free copy of Bulletin 41. Superior Tube Company, 2026 Germantown Ave., Norristown, Pa.

[1] Reg. T. M. Haynes-Stellite Co.
[2] Reg. T. M. Driver-Harris Co.
[3] Reg. T. M. International Nickel Co.

**Superior Tube**
**The big name in small tubing**
**NORRISTOWN, PA.**

*All analyses .010 in. to ⅜ in. OD—certain analyses in light walls up to 2½ in. OD*

West Coast: Pacific Tube Company, Los Angeles, California • FIRST STEEL TUBE MILL IN THE WEST

an Epsco transistorized

# TRANSICON DATRAC® ANALOG-DIGITAL CONVERTER

**can solve your data conversion problem . . . economically!**

designed FOR YOUR SYSTEM by system specialists who have pioneered the field of high-speed, reversible analog-to-digital conversion . . .

- **PRODUCTION ENGINEERED** to be the lowest-cost transistorized converters available anywhere.
- **MODULARIZED**—plug-in building-blocks permit assembly of over 50 standard models.
- **EASY TO USE**—no adjustments
- **HIGH SPEED**—up to 25,000 conversions/sec analog-to-digital; up to 100,000 conversions/sec digital-to-analog
- **HIGH POWER DIGITAL OUTPUTS**
- **DIGITIZES BOTH CURRENTS AND VOLTAGES**
- **PARALLEL AND SERIAL CODED OUTPUTS**
- **BUILT-IN EXPANDABILITY**—8-bit converters to 10, 12 or 14 bits; changing codes from binary to binary-coded decimal; making an analog-to-digital converter from a digital-to-analog unit

**. . . and an Epsco Exclusive: PROVEN RELIABILITY** One million hours of operation in installations around the world have proven DATRAC reliability. Now an all solid state TRANSICON DATRAC assures even greater performance.

New 6-page, 2-color brochure available with complete description of TRANSICON DATRACS. Write, wire or phone your local Epsco representative or contact, in the East: Epsco, Inc., Equipment Division, 588 Commonwealth Avenue, Boston 15, Massachusetts; in the West: Epsco-West, 125 E. Orangethorpe Ave., Anaheim, California.

**TRANSICON ANALOG-TO-DIGITAL CONVERTERS FOR . . .**

Data Logging Systems
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Digital Transmission over Telephone Lines
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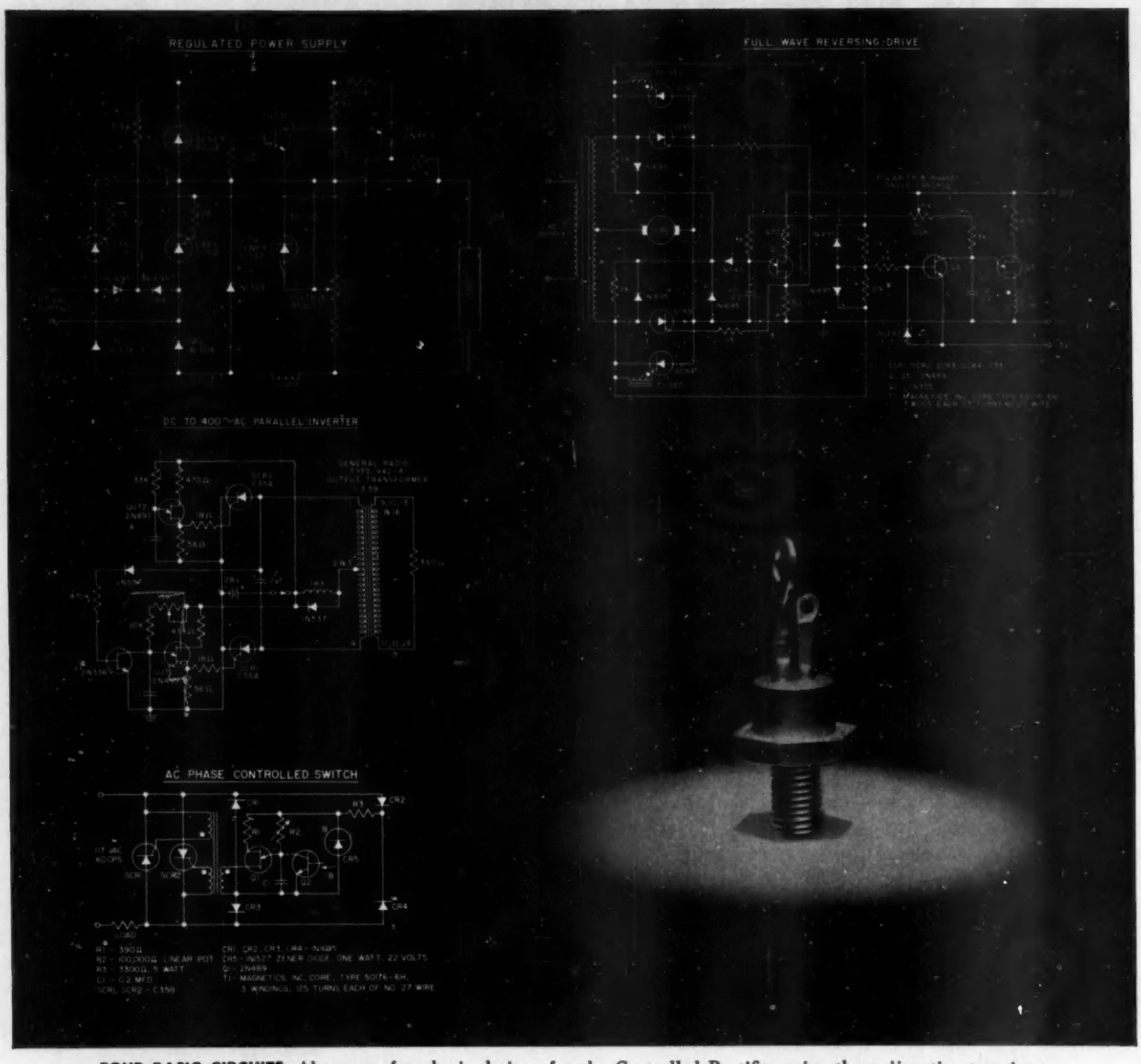
First in data control

CIRCLE 84 ON READER-SERVICE CARD

# General Electric Semiconductor News

## New prices, new circuits for




**FOUR BASIC CIRCUITS.** Above are four basic designs for the Controlled Rectifier using the unijunction transistor as the firing means. The unijunction is a precision trigger, putting out short, high current pulses. The frequency of these pulses will not vary with the supply voltage or temperature, yet can be variably controlled with a silicon triode from a low level feedback signal. Unijunction firing circuits are easily synchronized with 60 cycle line frequency. In short, the unijunction provides the simplest and least expensive means for precision firing of the Silicon Controlled Rectifier.

General Electric's new silicon medium-current rectifiers, Types 1N2154 thru 1N2160, are ideal as companion devices to the controlled rectifier for reverse-voltage protection and, also, for applications in full-wave circuitry.

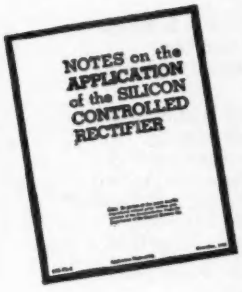
**SAMPLE LIST OF POWER HANDLING AND OTHER JOBS THAT CAN NOW BE DONE BETTER BY THE G-E CONTROLLED RECTIFIER**

- Converters, DC to DC, DC to AC
- Phase controlled DC power supplies, regulated & unregulated
- Frequency converter, current control
- Power switch for automatic temperature control electronic flash
- Reversible motor control
- AC variable speed induction motor
- Dynamic braking
- Light dimmers
- Thyratron replacement for relay drivers
- Pulse width conversion
- High speed printer for digital computer
- Welding control
- Ignitron firing
- Circuit breaker replacement

# revolutionary G-E Controlled Rectifier

"Controlled rectifiers may revolutionize the electrical industry." This statement was made a year ago by a respected news publication. Since then samples have been studied by hundreds of firms. Many new circuits have been developed which promise important improvements in functions, reliability, simplicity, accuracy and lower cost. In just one year prices have been reduced 75 percent (see chart below). And now, the G-E Silicon Controlled Rectifier is a standard, production-line item, warranted in writing and available at sharply reduced prices.

This is the time for design engineers to exploit the inherent advantages of the Silicon Controlled Rectifier in their circuit designs. Many applications are proved . . . the firing circuits have been refined . . . the product line is stabilized . . . and it makes sound economic sense. Call or write your G-E Semiconductor Sales Representative for complete details. The Controlled Rectifier is also available from many local G-E Distributors.



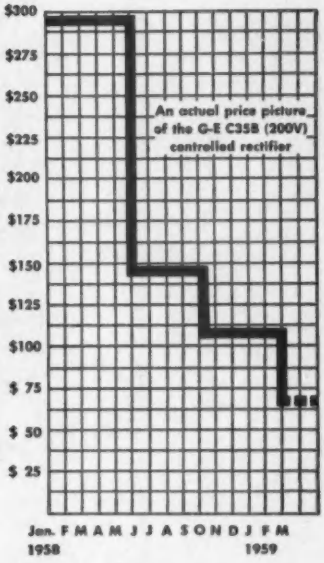

**HOW THE G-E CONTROLLED RECTIFIER WORKS.** The Silicon Controlled Rectifier is a three junction semiconductor device for use in power control and power switching applications requiring blocking voltages up to 400 volts and load currents up to 16 amperes. Series or parallel circuits may be used for higher power applications.

The G-E Controlled Rectifier's reverse characteristic is similar to a normal silicon rectifier in that it represents essentially an open circuit with negative anode to cathode voltage. The forward characteristic is such that it will block positive anode to cathode voltage below a critical break-over voltage if no signal is applied to the gate terminal. However, by exceeding the forward break-over voltage or applying an appropriate gate signal the device will rapidly switch to a conducting state and present the characteristically low forward voltage drop of a single junction silicon rectifier.

**DETAILED NOTES** are available on the application of the G-E Silicon Controlled Rectifier, plus reprints of articles that have appeared in technical journals. Write to Section S16559, Semiconductor Products Dept., General Electric Company, Electronics Park, Syracuse, New York.

**STEADY PRICE DROP.** Since its introduction one year ago, the price of the typical G-E Controlled Rectifier has dropped more than 75 percent. This results from improved manufacturing techniques and volume production. The G-E Controlled Rectifier is now a production-line item, warranted in writing for one year and subjected to the same quality control tests imposed on all General Electric transistors and rectifiers.

**The G-E Controlled Rectifier is also available at even less cost (ZJ39L series) for use at 100°C and below, with currents up to 10 amperes.**




**MAXIMUM ALLOWABLE RATINGS (Resistive or Inductive Load)**

| | C35U | C35F | C35A | C35G | C35B | C35H | C35C | C35D |
|---|---|---|---|---|---|---|---|---|
| Continuous Peak Inverse Voltage (PIV) | 25 | 50 | 100 | 150 | 200 | 250 | 300 | 400 volts |
| Transient Peak Inverse Voltage (Non-Recurrent<5 millisec.) | 35 | 75 | 150 | 225 | 300 | 350 | 400 | 500 volts |
| RMS Voltage ($V_{RMS}$), Sinusoidal | 17.5 | 35 | 70 | 105 | 140 | 175 | 210 | 280 volts |
| Average Forward Current ($I_F$) | Up to 16 amperes | | | | | | | |
| Peak One Cycle Surge Current ($I_{surge}$) | 150 amperes | | | | | | | |
| Peak Gate Power | 5 watts | | | | | | | |
| Average Gate Power | 0.5 watts | | | | | | | |
| Peak Gate Current ($I_G$) | 2 amperes | | | | | | | |
| Peak Gate Voltage ($V_G$) (forward) | 10 volts | | | | | | | |
| Storage Temperature | −65°C to +150°C | | | | | | | |
| Operating Temperature | −65°C to +125°C | | | | | | | |

| CHARACTERISTICS (At Maximum Ratings) | C35U | C35F | C35A | C35G | C35B | C35H | C35C | C35D |
|---|---|---|---|---|---|---|---|---|
| Minimum Forward Breakover Voltage ($V_{BO}$) | 25 | 50 | 100 | 150 | 200 | 250 | 300 | 400 volts |
| Maximum Reverse ($I_R$) or Forward ($I_F$) Leakage Current (Full Cycle Average) | 6.5 | 6.5 | 6.5 | 6.5 | 6.0 | 5.5 | 5.0 | 4.0 ma |
| Maximum Forward Voltage ($V_{F\ AVG}$) | 0.86 volts (Full Cycle Average) | | | | | | | |
| Maximum Gate Current To Fire ($I_{GF}$) | 25 ma | | | | | | | |
| Maximum Gate Voltage To Fire ($V_{GF}$) | 3 volts | | | | | | | |
| Typical Gate Current To Fire ($I_{GF}$) | 10 ma at +1.5 volts (Gate to Cathode Voltage) | | | | | | | |

**ZJ39L Series—lower cost series with ratings similar to above, but for use up to 100°C maximum, with forward current ratings up to 10 amperes.**
**ZJ50 Series—a high-current series now in development, and available on a prototype-sample basis.**

GENERAL ELECTRIC

CIRCLE 85 ON READER-SERVICE CARD

**EAI** PACE Computers Put Central Control At Your Fingertips

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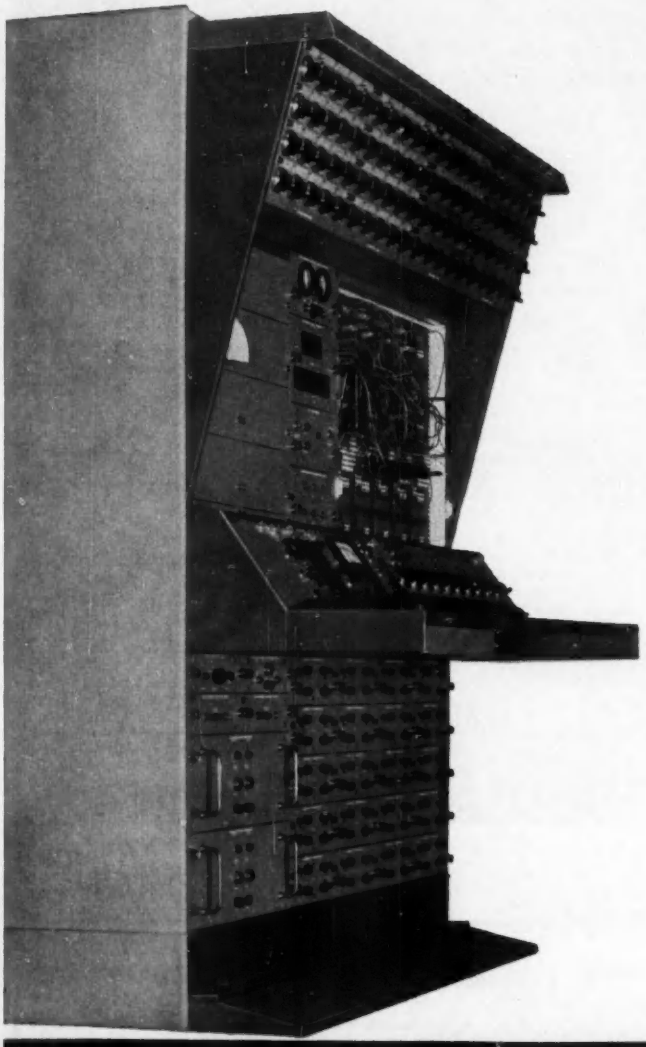


You can expect, (and be sure you'll get) the utmost in working accuracy and fine construction from every PACE computer. It's simple, we build more in – you get more out. But you will have to actually sit at the console to appreciate some of its very finest points.

Take our control panel for instance. *Every* important control is within easy reach from a sitting position. Including *all* coefficient potentiometers. Quick adjustments are easy, and the panels are sloped for restful operation through the very longest day.

Examine the patch panel. Modular grouping of components reduces patching time to one third that of other systems. Keeps cords short, eliminates tangle and clutter. And for legibility it is the model of the industry.

The completely electronic Digital Voltmeter reduces by two thirds the time needed for setting coefficient potentiometers. Presents the component address immediately too. No guesswork needed here.

Within easy view, central overload indicators tell visibly and audibly when improper operation of any component occurs *including* non-linear equipment.

Words could describe the fully Automatic Scanning of all components recorded by the High Speed Printer at 200 lines a minute. And the merits of Extended Read-out which allows you to select any component in the system for read-out by merely touching a button. But we think you should see this in action.

These are the subtle refinements developed in years of designing, building and operating more general purpose analog computers than all other computer manufacturers combined. We call it Human Engineering. Again, you will have to *see* for yourself. We will be glad to arrange a demonstration or send you literature. Write today!

ELECTRONIC ASSOCIATES Incorporated

## ELECTRONIC ASSOCIATES INC.

LONG BRANCH, NEW JERSEY

# IRE Show:

## Markets in the Madhouse

New York City's behemoth Coliseum was simply not big enough to hold the 1959 IRE show. A veritable madhouse of 60,000 engineers, scientists, salesmen, and students clogged the aisles from show opening to closing, overran the 950 separate exhibitors displaying wares ranging from tiny semiconductor circuits, visible only under a magnifying glass, to giant radar antennas that would have looked more at home on a mountain top.

**Big Business**

Despite the milling crowd, the smoke-saturated chaos, and the frantic pace, however, the 1959 show made an impression.

On the business side, practically every exhibitor had something to smile about. The impact of accelerated government spending for space, missiles, and aircraft, is being felt all along the line—from component makers to system suppliers. It made for an optimistic air that contrasted sharply with last year's gloom.

**More on computing-control**

But even more encouraging, at least to many suppliers, was the continuing spread of electronics to industrial areas, control for one. Industrial applications of computing-control, for example, continues to gain momentum. And talk is giving way to actual installation. A show visitor could hear details about computers going into chemical plants, petroleum refineries, steel mills, gas utilities, electric generating plants, and even an automobile plant. Exhibitors were buzzing about a computing-control market study which predicted a $100-million industrial market in 1960.

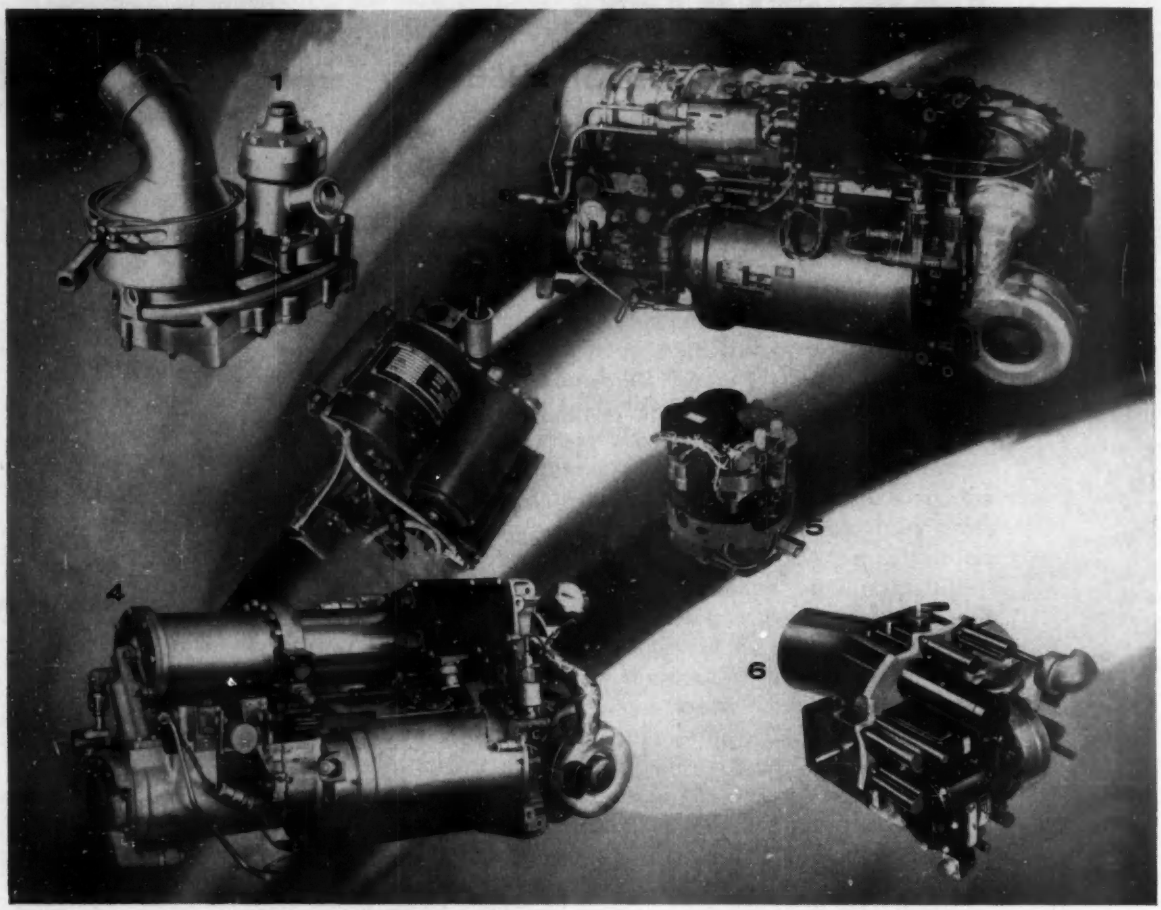
**The trend to digital logic**

Most of the 950 exhibitors had something new to show. And some new patterns could be seen forming. For example, there's renewed interest in the use of digital building-block techniques for logic circuitry. Manufacturers are making a variety of digital devices that will breadboard almost any system a control engineer's originality can create. Typical devices seen at the IRE show:

- Miniaturized magnetic shift register, smaller than the top of a thumb, displayed by Epsco and CK Components, Inc.
- Digital building blocks—both transistorized and vacuum-tube circuits—for logic circuitry, shown by Engineered Electronics Co.
- Transistorized circuit modules—amplifier, assymetrical flip-flop, diode AND gate, diode OR circuit, emitter follower amplifier, and inhibitor—all being offered by Kellog Switchboard & Supply Co., Computing Control Co., Inc., Digital Equipment Corp., and Harvey-Wells Electronics.
- Logic unit board containing 24 logic units, developed by General Mills' Mechanical Div. The units, connected by patching with short jumper wires, can be used singly or in pairs to form almost any circuit required in a digital computer.

More logic circuitry in control means that related equipment can do more things, become more automatic. But a problem loom-

# DELIVERED—thousands of missile APUs




1. *Solid propellant—hydraulic output* 2. *Liquid propellant—hydraulic and electric output* 3. *Solid propellant—electric and mechanical drive output*
4. *Liquid propellant—hydraulic and electric output* 5. *Solid propellant—hydraulic and electric output*
6. *Solid propellant—hydraulic, electric and steering outputs*

**AiResearch** has designed, developed, manufactured and delivered thousands of missile accessory power units. Extremely reliable and lightweight, these various solid and liquid monopropellant APUs are completely self-sustaining within the missile system. Designed to minimum space and weight requirements, they are built to withstand high G loading and severe temperature extremes.

The several units pictured above provide hydraulic, electrical and/or steering surface control depending on the customer's requirement. Delivered horsepower ranges from 1.2 to 35 h.p. over hot gas operating durations from 30 seconds to 20 minutes. Electrical regulation is maintained as closely as ±½%. A significant advance in missile APUs is unit #6 pictured above. This package represents the first integrated hydraulic and electrical power unit providing a steering surface actuation system.

These tailored systems utilize the extensive hardware experience and complete laboratory, test and production facilities of AiResearch needed for quick and efficient quantity production of complex APU systems. AiResearch is the world's largest and most experienced manufacturer of lightweight turbomachinery—the key component of its APU systems. Your inquiries are invited.

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 CIRCLE 87 ON READER-SERVICE CARD

ing more important is how to go economically from the midget-sized information signal to one big enough to operate a controller. One possibility in the offing, say makers of logic equipment, is the solid-state thyratron (CtE, April '59, p. 79). Both General Electric and Westinghouse, as expected, showed such units.

**Make them smaller**

Another area that indicated renewed interest is miniaturization. RCA exhibited the results of a program of microminiaturization, showed how it has achieved a parts density of 600,000 components per cubic foot of space. Midway through the IRE show, Texas Instruments "topped" the RCA claim when it unveiled a solid-state circuit made of a single crystal of silicon for which TI President Patrick Haggerty, at a press conference, boasted a practical density of 25 million components per cubic foot.

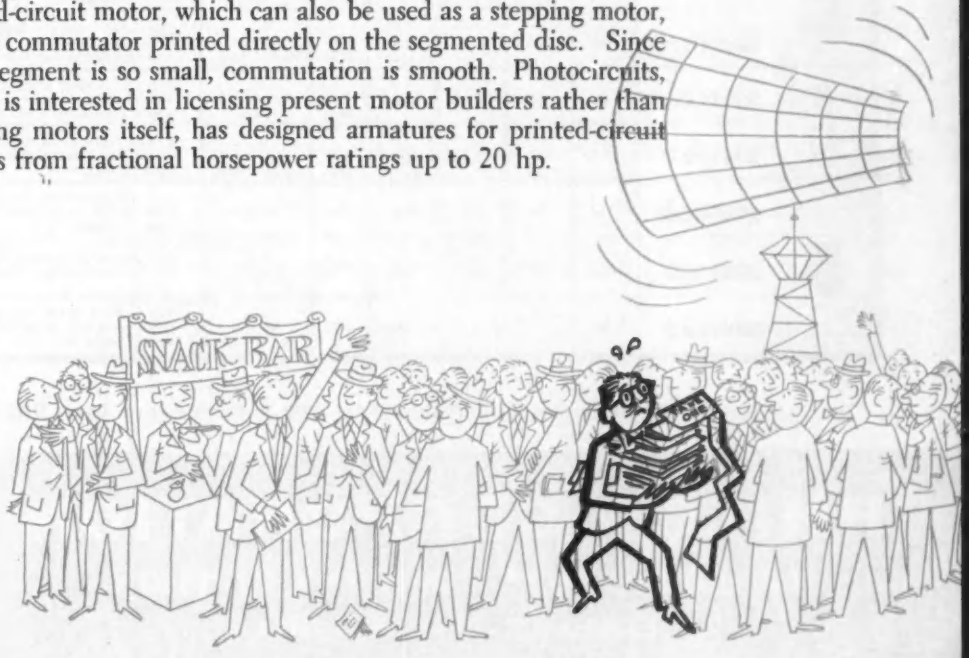
[A month earlier, at the Solid States Circuits Conference in Philadelphia, RCA had described work with similar silicon "circuits", claimed the development of small logical arrays such as multiple AND and OR gates. RCA said that densities of 100 million parts per cubic foot will be practical.]

Also still in the development stage, the new TI circuit has been used to build such devices as a multivibrator and an oscillator. Haggerty pointed out that his company could incorporate a wide range of capacitance and resistance into such devices, but that it had no luck with inductance.

[Bell Telephone Laboratories has a new, four-terminal field-effect semiconductor device that has no analog in either electron tubes or transistors. It can act as a "gyrator", a nonreciprocal transformer that inverts impedances, and should be able to make a small capacitor look like a high-Q inductor. This may solve TI's problem.]

**Printed-circuit motor**

Still another development that excited a lot of interest was a printed-circuit motor displayed by Photocircuits Corp. This company has replaced the wound armature of a dc motor with a thin, flat, copper printed disc of one-eighth the weight, to cut the overall weight of a motor by two-thirds in the 1-hp range. The printed-circuit motor, which can also be used as a stepping motor, has its commutator printed directly on the segmented disc. Since each segment is so small, commutation is smooth. Photocircuits, which is interested in licensing present motor builders rather than building motors itself, has designed armatures for printed-circuit motors from fractional horsepower ratings up to 20 hp.



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These transistors are available in production quantities, for use in teletypewriters, control amplifiers, ignition systems, mobile radios and desk calculators (2N1124); servo amplifiers, voltage regulators and pulse amplifiers (2N1125, 2N1126, 2N1127); medium power audio and switching applications (2N1128, 2N1129, 2N1130).

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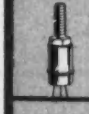
| TYPE | $V_{CB}$ Max. (Volts) | $V_{CES}$ Max. (Volts) | Peak $I_C$ (Amps) | P Max. (Watts) | $F_{\alpha b}$ (MC) | Beta | Applications | PRICE |
|---|---|---|---|---|---|---|---|---|
| **2N1124** | 40 | 35 | 0.5 | 0.3 | 0.4 Min | $h_{fe}$ 40 Min | For high voltage general purpose use in amplifier and switching. Small signal beta controlled. | $1.30 |
| **2N1125** | 40 | 40 | 0.5 | 0.3 | 1.0 Min | $\overline{h_{fe}}$ 50-150 @ 0.5 amp | For high voltage, higher frequency industrial amplifier and switching systems. Large signal beta controlled. | $1.90 |
|  **2N1126** | 40 | 35 | 0.5 | 1.0 | 0.4 Min | $h_{fe}$ 40 Min | 1 watt version of 2N1124 for servo amplifiers and relay actuators. Small signal beta controlled. | $1.80 |
| **2N1127** | 40 | 40 | 0.5 | 1.0 | 1.0 Min | $h_{FE}$ 50-150 @ 0.5 amp | 1 watt version of 2N1125 for servo amplifiers and control systems. DC beta controlled. | $2.40 |
| **2N1128** | 25 | 18 | 0.5 | 0.15 | 1.0 | $h_{fe}$ 70-150 | For low distortion, high level driver and output application. Small signal beta controlled. | $ .95 |
| **2N1129** | 25 | 25 | 0.5 | 0.15 | 0.75 | $h_{FE}$ 100-200 @ 0.1 amp | For high gain general purpose amplifier and switching. Typical DC beta 165. | $1.10 |
| **2N1130** | 30 | | 0.5 | 0.15 | 0.75 | $h_{FE}$ 50-165 @ 0.1 amp | For higher voltage, higher level amplifier and switching applications. Typical DC beta 125. | $ .95 |

**Available in Production Quantities—Also Available from Local Distributors**

## PHILCO CORPORATION

LANSDALE TUBE COMPANY DIVISION

LANSDALE, PENNSYLVANIA

TRANSISTOR CENTER U.S.A.

Control ENGINEERING MAY 1959

# New Meaning for Old Words

Production control is a workaday phrase that should need no explanation. But in examining some ambitious projects for automatic production control, we find a divergence of intent. To control engineers it means instrumentation and control of processes and machines to make them carry out precalculated, fixed schedules. To production planning people it infers scheduling, inventorying, warehousing, and order-handling. Now, however, through joint efforts to make these operations automatic, both are beginning to see a blending and enlargement of their versions. The common version emerging: control in accordance with variable schedules that are automatically and continuously calculated. Three cases demonstrate the trend in meaning and method.

• A steel company has requested bids on a system for automatically scheduling the entry and withdrawal of ingots into and out of soaking pits. The company intends that the system will digest metallurgical data on the "heat" from which each ingot has been poured and on what ingots are located where in the pits, as well as orders for the hot rolling mill. It will then calculate and carry out optimum schedules for storage and retrieval of ingots. Each time an ingot is entered or withdrawn, the system is to calculate a new optimum schedule.

• Integrated pipeline control is the object of a contract written by a gas-pipeline operating company. A general-purpose scientific computer will schedule the contents of the line, set the control points of compressor stations along the line, monitor conditions at well-heads and at compressor stations, and print off-normal data.

• Application of operations analysis techniques across the production board is under way at a paper company. Included are order-handling and warehousing, and the scheduling of paper machines, evaporators, beaters, digesters, and grinders. The company finds that the further it gets into the analysis, the more often it must seek the help of control engineers within its organization. The control engineers are able to give sound advice on the technical and economic feasibility of mechanizing the scheduling and warehousing problems involved, and just as important, they are showing how to tie in the process control systems now on the machines and equipment.

A higher level of production control will result from the merging of the efforts of the two key engineering groups, both of which bring practical know-how and new techniques to the job, and both of which will, in the process, radically improve their practice of production control.

W. E. Vannah

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# Control Rods for Power Reactors— **Is Speed a Problem?**

**THE GIST: One of the more controversial areas of nuclear reactor control is the operating speed of control rods. There appears to be two schools of thought, one advocating ultra-high speeds, the other defending more moderate speeds. In this article, the authors carefully analyze the issue with respect to power reactors, and show that in most cases safety requirements determine the proper speeds. Excellent results have been achieved by distinguishing between relatively slow rods for start-up and normal operation, and faster "safety" rods for rapid shutdown.**

**PAUL BRAFFORT and JACKY WEILL**
**French Atomic Energy Commission**
(Translation by M. Mamon, ITT Laboratories)

In much of the literature on nuclear reactor controls there seems to be a wide difference of opinion about proper operating speeds for control rods. To some extent this can be explained by the advent of automatic controls: early reactors were manually controlled and safety standards in force when they appeared dictated rather sluggish movement of the rods; with time and experience, control became automatic and rod speeds increased considerably. However, this normal evolution does not explain all: views still differ and advocates of both slow and fast rod operation can still be found.

Consequently, there must be some basis for the divergence—and some solution to the problem consistent with modern safety requirements.

For a start, consider the schematic reactor control system in Figure 1. This is nothing more than a reactor slaved to its nuclear power level. Here the system realizes the following transformations:

1. The reactor transforms a *reactivity* $\rho$ (produced by control-rod position) into a neutron density or power level $n$.
2. The ionization chamber and amplifier transform this neutron density into an electrical potential V.
3. The controller combines this potential with other input signals to produce an error voltage $\epsilon$.
4. The servo transforms this error signal into a corresponding rod position or *reactivity*, and the cycle is complete.

With transfer functions for all of these, it is possible to obtain an open-loop transfer function for the entire system. A classical study of the Nyquist diagram of this function will then reveal the rod speeds. Transformations 1 and 3 above constitute delicate points; therefore, before any attempt is made to determine rod speeds, system peculiarities and effective magnitudes of physical parameters must be taken into account.

## The reactor—a nonlinear element

In transformation 1, the reactor serves as an operator, transforming reactivity $\rho$ into a particular neutron density $n$. This indirect operation distinguishes the reactor from classical industrial systems wherein

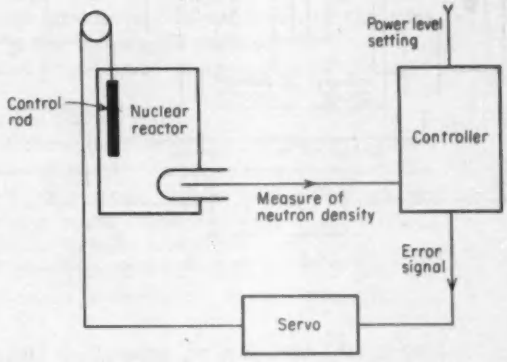



*FIG. 1. Simple control system for a low-power reactor.*

it is possible to exercise direct control of the power level (by, for example, regulating fuel flow to a burner). In the reactor, rod position determines the reactivity, i.e., a quantity that is bound to the derivative of the neutron density as a function of time. For low power ($\rho < 10^{-2}$) this nonlinear relation has been linearized to yield the system transfer function:

$$\frac{L[\delta n]}{L[\rho]} = \frac{n_o}{\tau_o} \frac{\prod_1^{\circ}(p + \lambda_i)}{\prod_1(p + p_i)} \qquad (1)$$

where $L$ symbolizes a Laplace transformation; $n_o$

represents the neutron density at equilibrium; $\tau_o$, the mean life of neutrons in the pile; $\lambda_4$, a decay constant; and $p$, a complex variable that permits determination of the amplitude and frequency response of the reactor for a sinusoidal variation of reactivity.

Actually, this linearization is incomplete, because the equilibrium power level $n_o$ appears in the transfer function. This is undesirable. Moreover, experimental checks (Ref. 1) notwithstanding, application of the above approximation requires a cautious approach. In fact, a study of the rod-positioning servo requires prior knowledge of response to signals of the Heaviside type; the linearization must be compatible with high-frequency considerations.

If $\phi$ represents the phase angle between reactivity and power level, tan $\phi$ should be a linear function of the oscillation $\omega$. However, simulation and experience indicate that this is not the case (Ref. 2).

The foregoing clearly demonstrates the better approach, i.e., simulation of, rather than linearization of, the kinetic equations of the reactor.

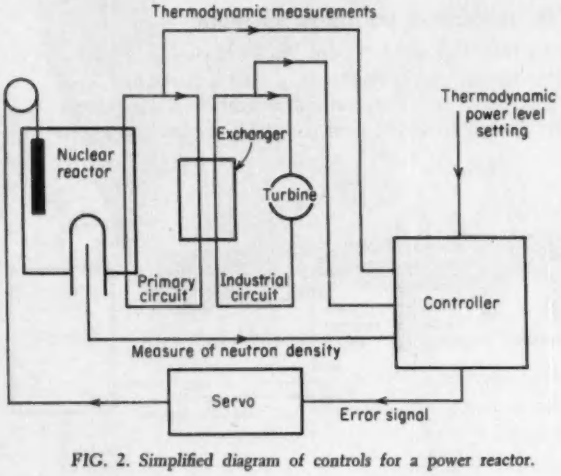



*FIG. 2. Simplified diagram of controls for a power reactor.*

## The heat circuits

The oversimplified block diagram of Figure 1 corresponds to a reactor with very low power output. For a power reactor, one that delivers energy to a turbine, for example, the thermodynamic or heat cycle must also be taken into account. Figure 2 shows a classical example of this type of reactor. Here, the control system is designed to stabilize the heat power delivered to the turbine rather than the flux level in the reactor.

For a simple understanding of system behavior, let $T_u$, $T_p$, and $T_i$ represent the mean temperatures of the uranium, the primary fluid, and the industrial fluid; and let $w$ represent available power at the turbine. With first approximations and the aid of operational calculus, the following equations may be written:

$$\left.\begin{aligned} L[T_u] &\cong (\gamma L[n])/(p + \lambda_1) \\ L[T_p] &\cong \frac{p\lambda_1 L[T_u] - \lambda_2 L[w]}{(p + \lambda_1)(p + \lambda_2)} \\ L[T_i] &= \frac{\lambda_1 L[T_p] - L[w]}{p + \lambda_2} \end{aligned}\right\} (2)$$

These equations show that any disturbance of the neutron density has an effect on the thermodynamic power delivered to the turbine. The time constants $1/\lambda_1$ and $1/\lambda_2$ determine the "sensitivity" of the turbine.

Temperature effects of the combustible and the moderator on the reactivity will not be analyzed here. It is assumed these will be accounted for during simulation of the entire system (Ref. 3).

## The error signal

Now consider the transfer produced by the controller. Figure 2 shows the controller receiving several input signals. In general, the transfer function of the neutron detector can be neglected (Ref. 4). In an ionization chamber, for example, the transfer function is essentially an RC network with a time constant of the order of $10^{-2}$ sec. This becomes insignificant when compared to other time constants in the loop. The same is true of other types of neutron detectors. Transfer functions of the temperature-measuring equipment can also be neglected, for their time constants, too, are small when compared with those of the thermodynamic circuits. This simplifies to some extent the approach to the error-signal problem.

Ordinarily, classical servo techniques are applied to control the nuclear power level. Assume an error signal of the type $\epsilon = (n_o - n)/n_o$, where $n_o$ is the power level at which the reactor must be stabilized. Here the term $1/n_o$ is used simply to eliminate the $n_o$ in the closed-loop transfer function.

Next, a suitable correction factor must be added—one which corresponds to the nonlinear character of the reactor itself. The most suitable one, of course, is the reactivity $\rho$ or its first approximation $(dn/dt)/n$.

If the error signal thus constructed directly controls the reactivity (which is defined as a function of the control rods), then, for correct response, the rods would require almost infinite speed.

Suppose, on the other hand, that the error signal controls rod speed rather than rod position. In this case, when the error equals zero, reactivity $\rho$ need not be zero. In fact, it could be dangerously high. So here again, to avoid this condition, a term proportional to $\rho$ must be used for error.

Similar reasoning would apply to the control of $\rho$ or $d\rho/dt$ with an error signal of the form $(x - x_o)x/_o$, where $x$ might be any measured temperature.

One way to resolve this apparent dilemma is to simultaneously slave both $\rho$ and $d\rho/dt$ to the error signal $\epsilon$. This is done by distinguishing between

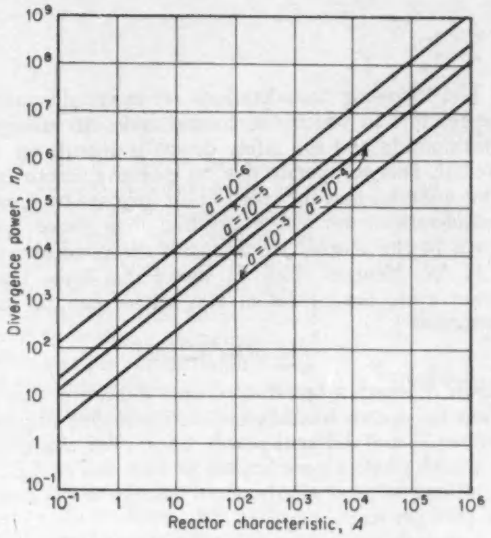



*FIG. 3. Divergence power as a function of the reactor characteristic.*

two groups of rods, one slaved to position, and the second to speed. According to Courtot, the maximum speeds of these two groups can be quite different (Ref. 5). Usually limits are imposed by using saturating electrical or electronic systems to produce the error signal.

In any case, since reactivity is limited in absolute value (barring any fault in the controller or servo) the slope of the reactivity need not be limited so long as the loop gain doesn't produce oscillations. Actually, this corresponds to limiting $d\rho/dt$ to values below 1,000 pcm/sec; i.e., below a limit which has never yet been exceeded.

From the foregoing it becomes obvious that the stability criterion alone does not lead to any practical limitation of control-rod speeds.

## Control of the rods

Since this study deals only with rod-controlled reactors, the fourth and final transformation, $\epsilon \rightarrow \rho$, is usually performed by some sort of electromechanical or hydraulic servo. The transfer function here is of the form:

$$\frac{L[\rho]}{L[\epsilon]} = R \frac{\omega_c^2\left(\frac{p}{\omega_1}+1\right)}{\frac{p}{\omega_1}(p^2+2\zeta\omega_2 p+\omega_c^2)} \qquad (3)$$

where $\zeta$ is the damping ratio; $\omega_1$ the resonant frequency of the system; $\omega_2$ the cutoff frequency; and $R$ the reactivity for unity error signal.

From this it becomes clear that loop gain, $\rho \rightarrow n \rightarrow \epsilon \rightarrow \rho$, is proportional to R and that no matter what form may be chosen for the error signal, system performance will increase as R becomes larger.

In studying the servo it helps to examine the system response to a sudden variation in rod position. Plotted response curves will show that, for higher values of $R$, the servo system restores the initial disturbance faster, and that here the rate of change of reactivity is much higher. The final value of the reactivity will always be smaller than the initial disturbance.

It follows therefore that, in principle at least, there is no limit to rod speeds. Again, this holds true only in the absence of any fault in the loop, particularly in the chain of measurements for $n \rightarrow V$ or in the formation of the error signal.

## Safety considerations

If neither the form of the error signal in the feedback loop nor the transfer function of the servo impose any limit on rod speed, what are the safety criteria that do lead to practical limitations? Essentially, they are of two types—nuclear and thermal. Nuclear criteria limit the power level and the absolute value of reactivity, and require that, during startup, the nuclear power becomes measurable before the reactor becomes critical. Thermal criteria limit temperature at various points in the system and the rate of temperature change in the fuel cells.

Under normal operation, automatic controls can satisfy all of the above conditions. However, they must still be satisfied when any one of the following faults occurs:

- malfunction of neutron or temperature detectors
- malfunction of the error-forming signal
- malfunction of the servo
- accidental introduction or extraction of the combustible in the absence of reactivity
- accidental introduction or extraction of the moderator
- fault in the cooling system

Any of these faults could occur during a power increase or when the reactor is in a stabilized condition. In any event, if the fault is not in the safety system itself, the safety rods would immediately drop to introduce negative reactivity.

Fortunately, all possible faults do not have the same degree of probability. Some require simulta-

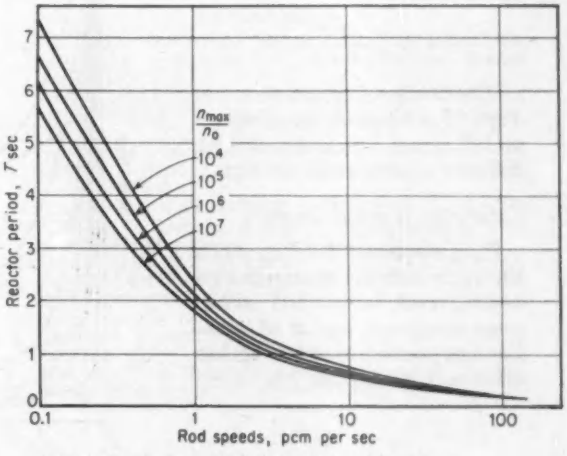



*FIG. 4. Maximum controlled speeds for different minimum reactor periods.*

neous occurrence of several faults. This must be taken into account and it should be remembered that absolute safety just doesn't exist.

## *Safety in starting*

In reactor operation, the start-up phase always demands a cautious approach. Here rod movement, hence reactivity, always occurs slowly. For this reason, it is possible to make a first-order approximation; i.e., it may be assumed that delayed neutrons grow linear with time ($d^2c_i/dt^2 = 0$). Under these conditions, the relation between $n$ and $\rho$ becomes

$$\frac{dn}{dt} = \rho \frac{n}{\tau} + \frac{\beta \tau_o}{\tau} \tag{4}$$

where $$\tau = \tau_o + \sum_1^6 (B_i/\lambda_i)$$

When reactivity varies linearly the following equation expresses bar speed in terms of reactivity per unit time:

$$\frac{dn}{d\rho} = \frac{\rho n}{a\tau} + \frac{\beta \tau_o}{a\tau} \tag{5}$$

The solution to this equation has already been presented by Raievsky (Ref. 6).

By letting $n_D$ represent the divergence power and $n_o$ the power corresponding to an initial reactivity $\rho_o$, divergence power can be expressed as

$$n_D = \sqrt{\frac{\pi}{2a\tau}}\, n_o \rho_o$$

or simply $$n_D = A\sqrt{\frac{\pi}{2a}} \tag{6}$$

where A equals $n_o\rho_o/\sqrt{\tau}$ and characterizes the reactor This shows that divergence power varies directly with the characteristic A, and is inversely proportional to the speed of the control rods.

If $n_{inf}$ represents the smallest power that can be measured by the reactor controls, then $n_D$ must be larger and the limiting rod speed becomes

$$a \leq \frac{\pi}{2} \frac{A^2}{n_{inf}^2} \tag{7}$$

The family of curves shown in Figure 3 is based on this equation and illustrates limiting speeds for different slow neutron reactors.

## *Safety at normal levels.*

$P_{max}$, the power level at which the safety rods act to stop the reaction, must be reached within some minimum period of time. For slow neutron reactors this has often been set at from 5 to 10 sec.

The following considerations are essentially valid for reactors in which the control rods can emerge continuously and the safety device is absent, or, if present, fails to operate due to excessive reactivity. This indicates that the speed limits imposed by these considerations are less imperative than those imposed by the start-up requirements described above.

H. W. Newson (Ref. 7) shows that for a low-power cycle the period of the reactor can be expressed as

$$T = \sqrt{\tau_o/2a \log (n_{max}/n_o)} \tag{8}$$

Figure 4 shows a family of curves indicating maximum rod speeds for different recommended reactor periods $T$, and different power ratios. For example, in a reactor with a cycle limited to 5 sec and an $n_{max}/n_o$ ratio of $10^6$, rod speeds would have to be less than 0.2 pcm per sec.

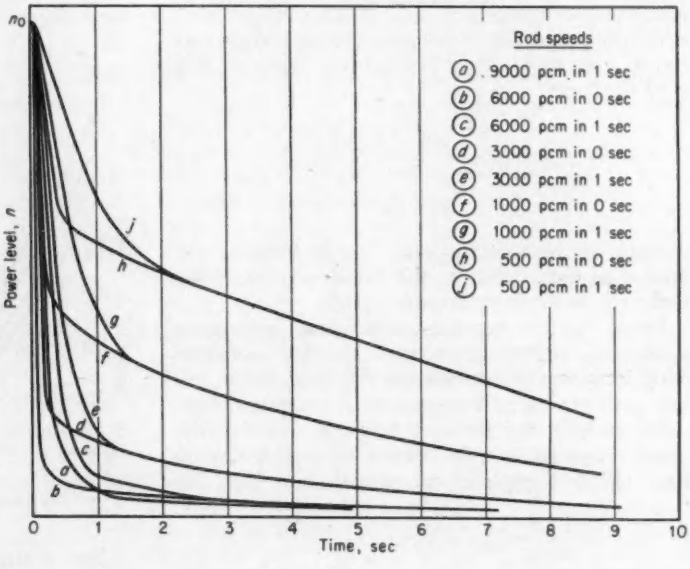
A second requirement for safe operation at normal levels involves the protection of the combustible bars or fuel elements. In heterogeneous piles, to protect the shield and insure longer life for the fuel elements, sudden temperature changes must be avoided. The only possible cause of such changes (other than failure of the cooling system, and this will be discussed later) is the progressive removal of the control rods.

If $\alpha$ denotes the temperature coefficient that affects reactivity because of the uranium temperature $\theta$, another expression of rod speed becomes

$$a < \alpha(d\theta/dt)_{max} \tag{9}$$

Thus, for a maximum temperature change of 1 deg C per sec and a thermal coefficient of 2 pcm per deg C, rod speed a must be less than 2 pcm per sec. This value corresponds to an exaggerated safety requirement to prevent a faulty operation or breakdown that would cause continuous withdrawal of the rods.

*FIG. 5. Curves show the rate of power drop at different rod speeds.*



### *Safety rod injection*

So far, rod speeds for start-up and normal operation have been considered. It remains to investigate the safety requirements for suddenly stopping the reactor. Here the most dangerous causes are partial or total failure of the cooling system. Seriousness of such a failure varies directly with the specific power of the reactor, i.e., megawatts per ton or total flux. Also, the thermal inertia of the uranium and of the cooling fluid remaining in the "accident area" slows down the temperature rise. These conditions would indicate that each reactor requires its own specific analysis. To illustrate procedure clearly, the following analysis is limited to reactors with thermal neutrons.

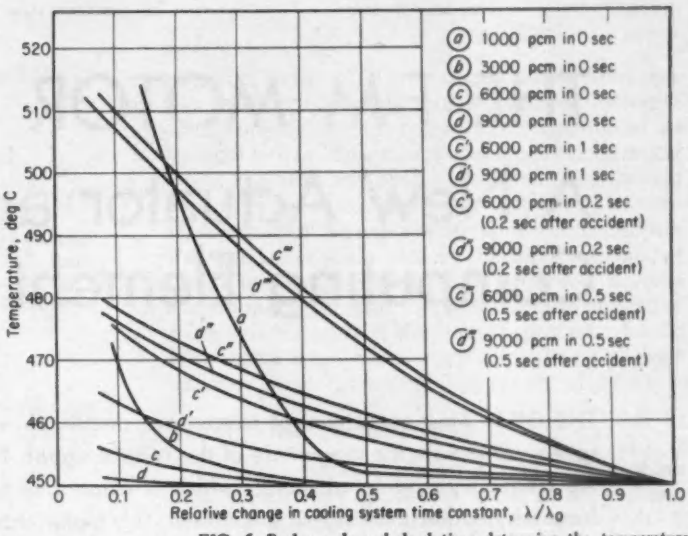



*FIG. 6. Rod speeds and dead time determine the temperature rise following a failure in the cooling system.*

Only the first few seconds, corresponding to the time required to evacuate maximum power, is of interest here. Figure 5 shows characteristics obtained on an analog computer. These curves represent power as a function of time with rod speed as a parameter. The power to be evacuated is determined by a graphical integration. From these curves, two facts becomes obvious: the anti-reactivity of the rods need not exceed 6,000 pcm; and the time required for injecting must be short. Nothing is gained, however, when this time is below 0.1 sec. To illustrate, the curves show that a drop of 6,000 pcm in 0.2 sec is more desirable than one of 500 pcm in 0 sec. Clearly, this proves that ultra-high-speed lightweight rods are of little interest.

It is worth noting here that the energy to be evacuated is also a function of the dead time between the fault-detecting signal and the actual instant at which the rods start falling. This dead time seriously affects the energy integral of these curves. For rapid injection, dead time should be less than the total fall time.

A second consideration in the study of injection speeds for safety rods is the increase in uranium temperature as a function of reduced cooling. For example, a pile of 30 megawatts per ton, cooled by heavy water, was studied on an analog computer to determine maximum temperatures of the fuel cells for different rod speeds. The abscissa of the curves in Figure 6 represents the relative change in cooling rates. These curves clearly show that, to prevent the temperature from exceeding that at which a phase change occurs in the uranium, it is necessary to

1) insure a minimum cooling from the start
2) use a bar speed that will produce sufficient anti-reactivity, and
3) reduce the dead time

## Conclusions

A number of authors have tried to demonstrate the need for ultra-high-speed rods. These same authors are puzzled by the relatively slow-speed rods used in such reactors as Saclay, Marcoule, Harwell, and Calder Hall. The foregoing proves that safety considerations justify this caution. For power reactors, temperature and flow changes are so heavily damped in comparison to the nuclear power, that further increase in rod speeds adds nothing to the turbine response.

In general then, rod speeds can be limited as follows: $10^{-6}$ $\delta k$ per sec for starting and compensating rods, and $2(10^{-4})$ $\delta k$ per sec for course-regulating rods. Here $\delta k$ represents a change in the multiplication constant of the core material and varies from one reactor to another. On the other hand, the drop time of safety rods should be as short as possible. Today such values are being used quite effectively in power reactors throughout the world.

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# THE F-M MOTOR
## A New Actuator and Computing Element

**THE GIST: Most small control motors are amplitude modulated, i.e., their speed varies with the magnitude of the control signal. This article introduces the frequency-modulated motor, which is responsive to changes in signal frequency rather than signal amplitude. This motor actually consists of two hysteresis synchronous motors, operating one inside the other; output speed equals the difference in their synchronous speeds.**

**What is the advantage of such an arrangement? It is apparent that the device is a gearless differential; output speed is proportional to the sum or difference of input frequencies. And where a gear train is used to reduce speed, rather than to increase torque, the F-M motor will yield the same low speed without backlash or gear inefficiency. In addition, normal line voltage fluctuations have no effect on motor operation. And the motor responds rapidly, since torque is available as soon as the frequency is changed. Too, synchronous torque for locking purposes is continuously available at the output shaft, even when it is standing still.**

**The following describes the motor and its characteristics, and gives brief application notes. A future article will cover detail design procedures for control systems incorporating F-M motors.**

**KURT BURIAN and**
**ROBERT S. JAMIESON**
**Parametrics**

The basic principle of the frequency-modulated actuator is not new; several such devices have been proposed in the past. The most popular of these, embodying a technique now being used, is an actuator system in which two synchronous motors drive a mechanical differential. In this setup, differential output shaft speed is proportional to the sum or difference of the frequencies applied to the two synchronous motors. The F-M motor, developed by G-M Laboratories, Inc., accomplishes the same purpose, but by essentially mounting one motor inside the other the sum or difference speed is obtained without the mechanical differential.

There are two configurations; Figure 1 shows the in-line version. The output shaft of the conventional motor *A* is integral with the rotating wound stator of motor *B* so that the stator of motor *B* rotates at the same speed as the rotor of motor *A*. Thus, if both motors are driven at equal speeds but in opposite directions, the output shaft will stand still. And if the speed of either motor is increased or decreased, the output shaft will turn at the difference speed, in the direction of the higher-speed motor. Again, if the two motors are run in the same direction, the output shaft will rotate at a speed equal to the sum of the speeds of the motors. Thus, smooth differential action results without using gears.

Figure 2 shows an alternate configuration of the F-M motor. In this case, the two motors are coaxial, with motor *B* turned inside out. Both configurations have advantages:

• *Shape* For the same power the coaxial version has a much greater diameter, but a shorter length.

TWO VERSIONS ARE AVAILABLE

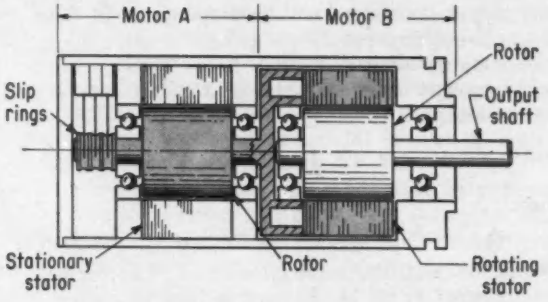



*FIG. 1. In-line version of F-M motor. This configuration features good heat dissipation and the possibility of making the torque-to-inertia ratios of the two motors very nearly equal.*

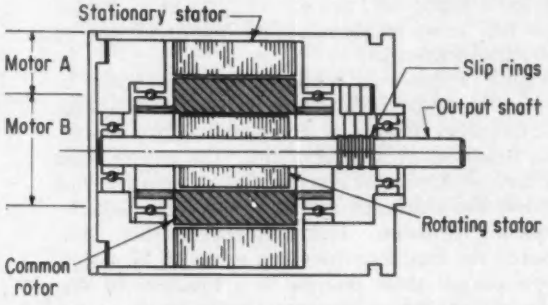



*FIG. 2. Coaxial version of F-M motor. This configuration features low brush speed and higher torque and inertia for the outside motor, an advantage when the motor is operated as a fixed-speed reference.*

• *Brushes* Brush speed is lower in the coaxial version, since the slip rings for motor *B* are on the output shaft and rotate at output speed.

• *Inertia* Motor *A* has the highest torque and inertia in both versions. But in the in-line version the torque-to-inertia ratio of motor *A* can be made close to that of motor *B*. This is not so in the coaxial version. However, if motor *A* is used as a constant-speed reference, the energy sink resulting from its higher inertia is likely to be an advantage in resisting reaction to transient speed changes.

• *Heat dissipation* The in-line type has a lower temperature rise because of its internal shape and greater external surface area.

The two motors are hysteresis synchronous units, featuring precise synchronous speeds, high synchronous torque, and the torque capability of accelerating any load that they can synchronize. The conventional type of dc-excited, salient-pole synchronous motor is not suitable for this application, since sharp transients in the input frequency resulting from slew commands can cause the motors (whether hysteresis or salient-pole) to fall out of step. Because of its low stall torque, the conventional synchronous motor might very well stop under this condition, whereas the hysteresis synchronous unit will simply accelerate the load to the new synchronous speed. Adjustable-speed hysteresis motors, operated at varying speeds by changing the supply frequency, develop approximately constant torque if the ratio of applied voltage to frequency is maintained constant. In the F-M motor application, supply frequency changes relatively little (for example, 20 cps out of 400 cps).

## *Performance characteristics*

The characteristics of the output motor of an F-M actuator are similar to those of an ordinary hysteresis synchronous motor of the same physical size. Figure 3 shows the output torque vs. speed of a 1.062-in.-in-diameter eight-pole in-line unit. The input to motor *B* was 400 plus or minus 20 cps at 70 volts (5 watts maximum power). Motor *A* was rotating at 6,000 rpm, the synchronous speed of motor *B* when the input frequency to the latter was 400 cps.

The asymmetry in the output curve resulted from stalling the output shaft while torque measurements were being made. This caused a supersynchronous condition at frequencies lower than 400 cps, i.e., motor *B* was actually rotating faster than its exciting frequency. Under this condition torque falls off. This means that under any condition the F-M motor will speed up slightly faster than it will slow down, although the effect of windage partially offsets this asymmetry.

The in-line motor used to obtain the curve shown in Figure 3 can accelerate itself from stop to an output speed of 60 rpm in less than 5 millisec. A typical coaxial motor accelerated from 0 to 800 rpm in 20 millisec, driving a load consisting of a size 9 synchro and a clutch-brake. Generally response times are better than those of typical servomotors and reduction gear trains. For example, if an output speed of 150 rpm is desired from an eight-pole motor, one of the input frequencies is changed 10 cps. Therefore, if the input frequency is changed from 400 to 410 cps, the motor instantly develops 0.165 oz-in. of torque, motor *B* changes its speed from 6,000 to 6,150 rpm or 2.5 percent, and the energy stored in the inertia of the motor changes only 5 percent. In comparison, to obtain an output of 150 rpm from a conventional servomotor with its associated gear train, the motor must accelerate from a stand-still condition to full speed, while the energy level changes from 0 to 100 percent. The load requires the same energy change to accelerate it in both cases.

Also, in voltage-controlled motors, the electrical time constants are significant and current must flow in the windings before the motor moves. In the F-M motor, torque is available as soon as the fre-

quency is changed. And since frequency changes can be accomplished in microseconds, F-M motors can be made to respond very rapidly.

Since both units are continuously rotating within the F-M motor, synchronous torque is available even though the output shaft is standing still at zero displacement. The usual stiffness constant, or ratio of torque developed to displacement angle, is meaningless. This makes the F-M motor useful for maintaining accurate position and velocity during vibration and shock.

Although Figure 3 shows a frequency range of 380 to 420 cps, F-M motors have been used over a range of 350 to 450 cps. It is also possible to design the motor for higher frequencies, although it shares the problems of efficiency, ball bearing life, and size

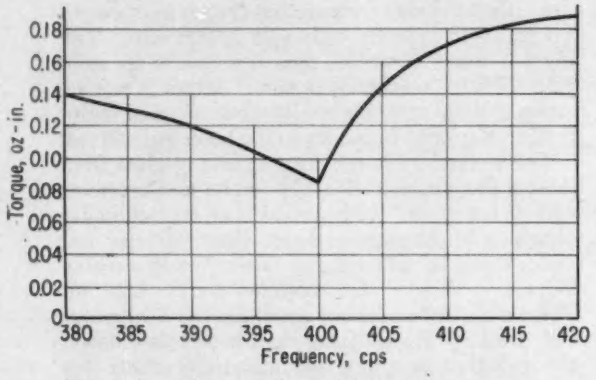



*FIG. 3. Torque-frequency characteristic for in-line motor. Reference motor operates at a constant frequency of 400 cps.*

with conventional motors currently being designed for the new aircraft and missile frequencies.

## *How and where to use the motor*

The F-M motor can be used as a low-power, open-loop, adjustable-speed drive, as a computing element, or as an actuator in closed-loop systems. The steady-state output speed $S$ is

$$S = (f_1 - f_2)120/N \text{ rpm}$$

where $N$ is the number of poles and $f_1$ and $f_2$ are the input frequencies in cps. The motor can be driven by two oscillators and amplifiers. If the variable oscillators are accurately calibrated over the frequency band that is of interest, then this system makes a smooth, accurate, open-loop, adjustable-speed source.

Computation using the F-M motor can borrow techniques and components from the telemetering field. There are many commercially-available transducers and oscillators which, used in conjunction with one another, will relate such parameters as pressure, acceleration, angular displacement, temperature, force, or velocity to a frequency change. By driving an F-M motor with these frequencies, in comparison with a fixed frequency or another variable, output shaft speed will be proportional to the sum or the difference.

Since output-shaft position is the integral of the input-frequency difference, the F-M motor can be used to integrate

$$\theta_o = K \int_o^t (f_1 - f_2)dt$$

where

$\theta_o$ = output shaft position

Two factors limit the accuracy of the F-M motor as an integrator: 1) the device used to read the output angle, and 2) the transient response capabilities of the motor. If the variable frequency does not change so rapidly that the F-M motor drops out of synchronism, it can integrate as long as the output shaft is allowed to turn. If its rate of frequency change is kept small, and several turns of its output shaft can be accurately measured, the motor can be a practical integrator.

Figure 4 shows an integrating accelerometer in which the output of an accelerometer with a variable-frequency output is compared with a stable, fixed frequency in an F-M motor. The output shaft position of this motor is a function of velocity, and controls the frequency output of a second variable-frequency oscillator. This frequency is then compared to the fixed frequency in a second F-M motor, whose output shaft position is a function of distance. This device has certain advantages in an inertial guidance system, such as the elimination of precision errors and more precise integration than is obtainable by standard electronic means.

Servomechanisms incorporating F-M motors fall into two classes: the floating type and the fixed type. In the floating type, the input to the servo controls the output frequency of a variable-frequency oscillator which drives one part of the F-M motor through a power amplifier. Another variable oscillator, whose frequency is controlled by output shaft position, drives the other half of the F-M motor. Any change in the input frequency is reflected in a new position of the output shaft and a balancing change in frequency of the second oscillator. This type of servo is useful for synchronizing two rotating components or for monitoring a frequency or a speed.

Such an inverter monitoring system is shown in Figure 5. The inverter under test excites motor A while motor B is driven by a variable-frequency power oscillator whose frequency is controlled by output shaft position. With a properly calibrated dial, frequency can be read out, since there is a different output shaft position for each different inverter frequency.

In the fixed type of F-M servo, one input to the F-M motor is taken from a stable fixed-frequency

oscillator. Input and output shaft positions are compared in a bridge arrangement and the output of the bridge controls the frequency of a second oscillator. Normally this oscillator would run at the same frequency as the fixed oscillator, but any disagreement in input and output generates a frequency change, causing the motor to turn and correct the output shaft position. Conventional synchros or potentiometers could be used to compare input and output position.

Both servo types have interesting characteristics. They are relatively independent of voltage variations, requiring only that the energy input be sufficient to provide a minimum value of synchronous torque. And both types can be made entirely without gears if torque amplification is not necessary. This eliminates gear backlash and compliance, and the power losses due to gear inefficiency.

Another advantage of the F-M servo results from its nonlinear gain. The motor can be made to accelerate at maximum for about half the time, and to decelerate at maximum the rest of the time. This feature, enhanced by the torque characteristics, allows the motor to drive to its final position in the shortest time, yet arrive with almost zero velocity. This means the servo can be made to have minimum overshoot, and yet not be overdamped. And since the shaft locks into synchronism at each new position or speed, no error signal is needed to maintain this condition.

## Relative complexity

A complexity comparison is difficult except for specific cases, but consider two simple position control systems—one an F-M type and the other using a conventional servomotor. Both can use synchros for input and output comparison. The power amplifiers for both systems can be similar, although the F-M servo will require two amplifiers. The function of the preamplifier in the conventional servo is replaced by a bridge-controlled oscillator in the F-M servo. One or two stages would suffice for this. The power amplifiers for the F-M servo can be much simpler, since they do not require signal-conditioning compensation. Thus it would appear that the F-M servo would have two more stages than the conventional servo, the increased cost being partially offset by the simpler design.

In the extreme, an F-M servo can be driven by two power multivibrators, since the square-wave output has no effect other than increased heat generation in the motor. The variable multivibrator can be controlled by using input and output shaft potentiometers that vary the positive bias return on the multivibrator grids.

In some cases the mechanical portion of the F-M servo can be much simpler than that of the conventional servo. If the gear trains and gear train housings can be eliminated, this reduces weight, bulk, and cost. It is probable that the power amplifier for the reference motor (in reality, a power oscillator) will not greatly exceed the cost of a precision gear train.

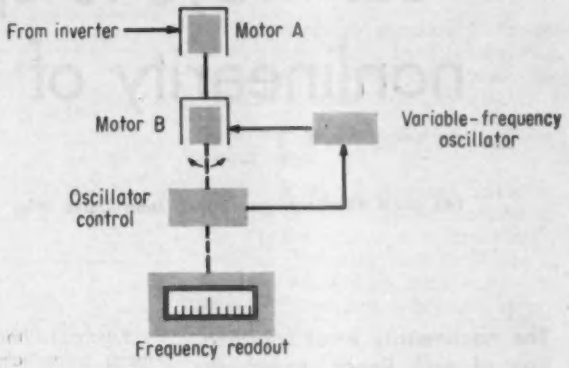



*FIG. 5. F-M motor system monitors inverter frequency.*

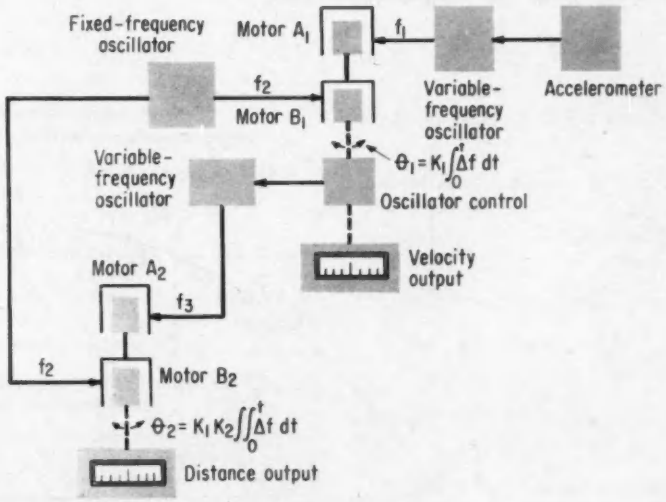



*FIG. 4. Accelerometer with frequency output proportional to acceleration feeds a double integrator composed of F-M motors.*

## System design

The F-M motor is a new device whose use will increase as system designers become familiar with its characteristics and capabilities. A future article will cover the detailed design procedure for incorporating this motor in various types of automatic control systems.

# Four ways to specify nonlinearity of linear transducers

TAI NIEN FENG, Avionic Div., John Oster Mfg. Co., Inc.

**The nonlinearity error specification of such linear transducers as potentiometers, pressure gages, and tachometer generators means little unless the reference point and input range are defined. With no reference point specified, theoretically there is an infinite number of values of nonlinearity for a given transducer. To eliminate disagreement between maker and user, a standard reference point should be used for specifying nonlinearity tolerance. Even better, contends Author Feng, would be the universal adoption of the same reference point—at two-thirds of anticipated maximum input. The article demonstrates the benefits of the proposed standard, and shows three other common ways to specify the reference point.**

Figure 1, line a, shows the ideal linear transducer with the origin as the reference value; line c, with the anticipated maximum input as reference; and line b, with an arbitrary point $x_o$ as reference. Curve $y = f(x)$ is the actual transducer characteristic. The nonlinearity $\Delta y$ is, at any value x, the difference between curve y and lines a, b, or c.

The equation $y = f(x)$ of a linear transducer exhibiting nonlinearity can, in general, be represented by an infinite series:

$$y = ax + bx^2 + cx^3 + dx^4 + \dots . \quad (1)$$

In most cases, the higher-order terms of x can be neglected, and on a per-unit basis Equation 1 becomes:

$$y = x - mx^2 \quad (2)$$

where m is a design parameter and hence fixed for a given transducer.

Line d in Figure 2 represents some ideal linear transducer, and $y = f(x)$ the actual transducer. At $x = x_o$, Equation 2 becomes:

$$y_o = x_o - mx_o^2 \quad (3)$$

The magnitude of any point y′ on d is: $y' = (y_o/x_o)\,x = [(x_o - mx_o^2)\,x]/x_o$

$$= (1 - mx_o)\,x \quad (4)$$

Then, from Equations 3 and 4, the nonlinearity $\Delta y$ is:

$$\Delta y = y - y' = x - mx^2 - (1 - mx_o)\,x$$

$$\Delta y = m\,(x_o x - x^2) \quad (5)$$

Equation 5 thus specifies the nonlinearity error at the output in terms of the reference point $x_o$ and the input value x. It applies to the general case, where $x_o$ can have an infinite number of values between the origin $x_o = 0$ and the anticipated maximum value $x_o = x_m$. Three definite and common ways of specifying nonlinearity, and a new proposed method, are of particular interest.

### Reference point is the origin

Here, $x_o = 0$. Thus, Equation 5 becomes:

$$\Delta y = -mx^2 \quad (6)$$

and the nonlinearity of Equation 6 is plotted in Figure 3. Note that the nonlinearity is zero at the origin and increases to minus $mx_m^2$ at maximum input.

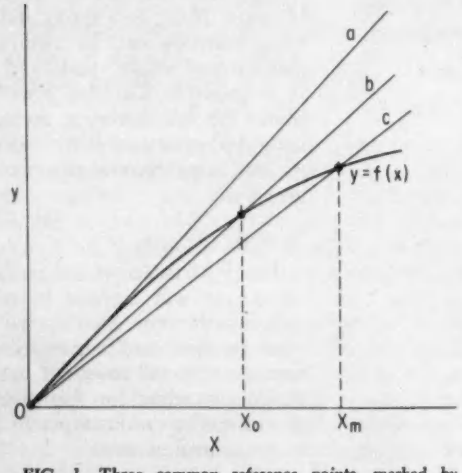



*FIG. 1. Three common reference points, marked by dots, specify nonlinearity of a linear transducer.*

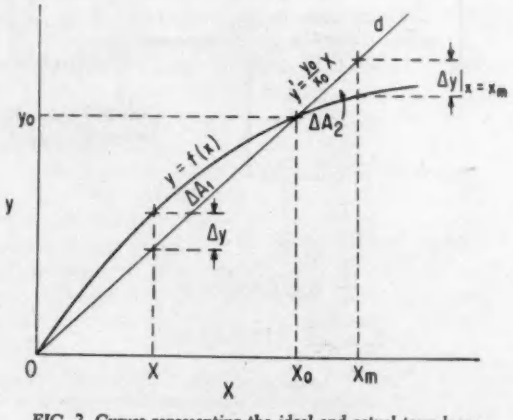



*FIG. 2. Curves representing the ideal and actual transducer define the nonlinearity error y in terms of $x_m$, $x_o$, and x.*

## HOW REFERENCE POINT CHANGES NONLINEARITY TOLERANCE

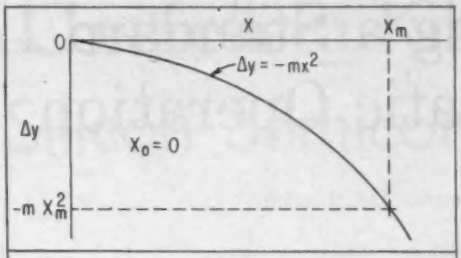



*FIG. 3. Magnitude of nonlinearity error when origin is the reference point.*

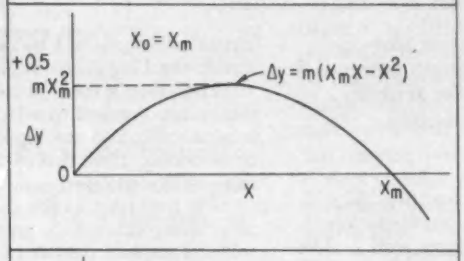



*FIG. 4. Magnitude of nonlinearity error when anticipated maximum input is the reference point.*

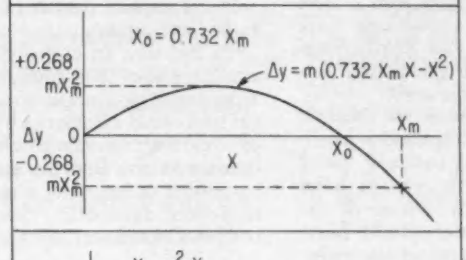



*FIG. 5. Magnitude of nonlinearity error when using "best straight line" as the ideal linear characteristic.*

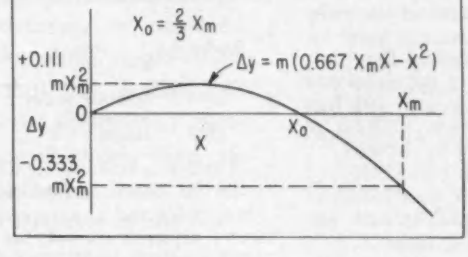



*FIG. 6. Magnitude of nonlinearity error when using the proposed reference of 2/3 maximum input.*

### Reference point is the anticipated maximum input

Here $x_o = x_m$ and Equation 5 yields:

$$\Delta y = m\,(x_m x - x^2) \qquad (7)$$

The nonlinearity for this case is shown in Figure 4. Here the nonlinearity is zero at the origin and maximum input, while the maximum nonlinearity is plus 0.5 $mx_m^2$.

### Reference point based on the best straight line

Here the best straight line means that $x_o$ is chosen such that the nonlinearity is a minimum and at $x_m$ is equal and opposite to the maximum nonlinearity between $0 \leqq x \leqq x_o$. The maximum nonlinearity is found by differentiating Equation 5 and setting the answer equal to zero. Thus:

$$x = (1/2)\,x_o \qquad (8)$$

Substituting Equation 8 into Equation 5 yields:

$$\Delta y \Big|_{x=(1/2)\,x_o} = (1/2)\,mx_o^2 \qquad (9)$$

When $x = x_m$, Equation 5 gives:

$$\Delta y \Big|_{x=x_m} = m\,(x_o x_m - x_m^2) \qquad (10)$$

$$\text{Let } \Delta y \Big|_{x=(1/2)\,x_o} = -\Delta y \Big|_{x=x_m}$$

Then: $x_o = (\sqrt{3} - 1)\,x_m = 0.732\,x_m$ (11)

Substituting Equation 11 into Equation 5 results in:

$$(\Delta y = m\,(0.732\,x_m x - x^2) \qquad (12)$$

This nonlinearity equation is shown in Figure 5. Here, by definition the maximum nonlinearity is equally divided, and equal to 0.268 $mx_m^2$.

### Reference point based on equal area

The proposed standard reference point is derived from the concept of the probability, or "equal-area", method. Referring back to Figure 2, the areas $\Delta A_1$ and $\Delta A_2$ are found by integrating Equation 5 between appropriate limits:

$$\Delta A_1 = m \int_0^{x_o} (x_o x - x^2)\,dx = (1/6)\,mx_o^3 \qquad (13)$$

$$\Delta A_2 = m \int_{x_m}^{x_o} (x_o x - x^2)\,dx = (1/6)\,mx_o^3 + (1/3)\,mx_m^3 - (1/2)\,mx_o x_m^2 \qquad (14)$$

Specifying that $\Delta A_1$ equals $\Delta A_2$ yields:

$$x_o = (2/3)\,x_m \qquad (15)$$

This is the proposed standard reference point. Substituting Equation 15 into Equation 5 gives:

$$\Delta y = m\,(0.667\,x_m\,x - x^2) \qquad (16)$$

The nonlinearity curve is shown in Figure 6; the nonlinearity goes from a plus maximum of 0.111 $mx_m^2$ to a minus maximum of 0.333 $mx_m^2$.

### The benefits

For the first two methods, the maximum nonlinearity reduces, or improves, roughly by a factor of two. Referring to Figures 5 and 6, the nonlinearity based on the proposed standard reference point is greater at $x = x_m$ when compared with the maximum based on the best straight line. However, the maximum nonlinearity using $x_o = (2/3)x_m$ will be equal to or less than the "best-line" method when $x$ is less than 0.95 $x_m$. Furthermore, the nonlinearity based on the proposed standard will be no greater than 0.111 $mx_m^2$ when $x$ is less than 0.80 $x_m$.

Thus, for the lower 95 percent of the input range, using $x_o = (2/3)x_m$ gives the minimum overall transducer error due to nonlinearity.

The proposed standard reference point of 67 percent of maximum input is also suggested as the "setting" or "trimming" point for obtaining the desired output value. It is the region around this point that would in all likelihood demand the highest accuracy, since a correctly-selected transducer usually operates in the region between 50 and 80 percent of maximum output.

# Converting a Standard Lathe to Automatic Operation

*IAN NICKOLS, Nickols Automatics, Ltd. (London)*

**$2,450 invested in a new control system gave an ordinary capstan lathe the same earning power as a high-speed automatic while retaining the flexibility of the old machine for small lot production.**

A stepping relay control system, costing $2,450, converted a standard capstan lathe to automatic operation suitable for either bar or chucking work. The new control, installed in an English metalworking shop, reduced lathe cycle time, eliminated one machine operator, and because of its flexible programming, produced small lots as economically as large ones.

Housed in a 19 x 10 x 6 in. cabinet the Nickols sequence control includes a stepping relay and a patch-cord programming panel. The programming panel interconnections are set to control the various lathe functions. These include opening and closing of the chuck jaws, feed-in of the bar, change of spindle speed and turret head position, and adjustment of the cross-slide and capstan slide feed rates.

Heart of the modernization is a standard four-bank, 25-position uniselector. The contacts of the uniselector —four rows of 25—are swept by a double arm, with four contacts at each end and indexed from position to position by a solenoid-operated ratchet mechanism.

On the lower half of the programming panel the 100 contacts from the relays are terminated in a matrix of 25 rows, four plugs to a row. One plug in each row is connected to the uniselector indexing circuit.

On the upper half of the panel, two sets of plugs correspond to the inputs and outputs from the lathe movements. Eighteen plugs labeled "motions" make up the inputs to the actuators on the lathe, operating such functions as speed selection and feed rate. Ten plugs designated "signals" terminate the outputs of the Microswitch circuits on the lathe. These operate when a particular machine function is complete.

Programming is done by interconnecting the plug-board, following a work sheet that shows the required lathe motions. The first lathe motion is initiated by connecting the output contacts on the first uniselector position to the appropriate motion plug. The stepping of the uniselector to this position energizes the circuit and operates the actuator on the lathe. When this motion is completed, the triggering of a Microswitch completes the circuit through the signal socket to the index plug on the uniselector.

The uniselector then indexes to the next output position, thus energizing the second machine operation. In this way operation timing avoids the complicated cam setting required on high-speed automatic lathes.

For easy maintenance, each function and signal circuit is brought out to an individual switch for quick visible checking of the machine operation.

With this system, modifications to the lathe are minimum. Applied to a Herbert 2D machine, no structural modification was made and only the actuators had to be added. Here two air cylinders provided the cross-slide movement, hydraulic check cylinders the stepless variable feed rates on the slide. A small-stroke 5-in. bore air cylinder indexed the six-tool turret head while a rack and pinion drive, operated from a large air cylinder, controlled the capstan slide feed through check cylinders.

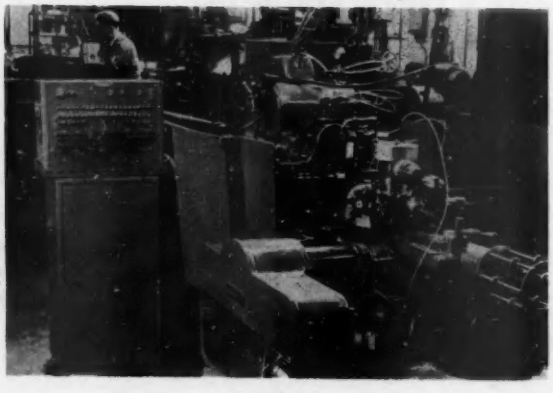
In this way, an ordinary capstan lathe has the same earning power as a high-speed automatic, and at the same time can produce small batch sizes uneconomical for high-speed automatics with their setup time and the cam cutting requirement. Production costs for small batches on the sequence controlled lathe thus become equivalent to large run quantities produced on normal high-speed automatics. Some figures on typical small batches show the savings that can be achieved.

| Batch size | Item | Cost of production | |
|---|---|---|---|
| | | Conventional production | Sequence control |
| 2,000 | Spherical washer | $2.21c | $1.32c |
| 500 | Special bolts | 3.80c | 2.13c |
| 2,000 | Dowels | 2.15c | 1.035c |

There is a labor saving advantage, too. With a conventional, hand-operated capstan on small batch work, an operator and a setup man are required. With automatic sequence control, the operator is up-graded to a setup man who programs the machine from the tooling layout. Thus the size of the labor force is reduced by one man. With operator cost averaging $40 a week (in England), an annual saving of $2,080 is realized.

Since the equipment cost $2,450, straight-line depreciation, spread over 10 years, is $245. Annual maintenance costs average $70.

*System applied to standard capstan lathe reduces cycle times by 25 percent.*



# Phase-Controlling Kilowatts With Silicon Semiconductors

**F. W. GUTZWILLER**
**Semiconductor Products Dept.**
**General Electric Co.**

**THE GIST: Electrically, the silicon controlled rectifier is the solid-state equivalent of a gas thyratron. And as such the three-element rectifier will conduct only when the anode is positive with respect to the cathode (during the positive half-cycle of the anode ac supply) and after the proper triggering signal has been applied to the grid (or gate). Once conduction has started, the gate loses control and the controlled rectifier continues to conduct until the anode turns negative with respect to the cathode. Power modulation is achieved, therefore, by varying the phase angle of the gate firing signal, so that the rectifier conducts for more or less of the positive half-cycle.**

**In phase-controlled applications, then, the method of firing the gate is a key factor. There are several ways to do this, one of the better being to use unijunction transistors as a source of the firing pulse. The combination of these two semiconductor devices offers simplicity, reduced size, and improved speed of response, power gain, and reliability. Author Gutzwiller discusses the basic unijunction-transistor/controlled-rectifier circuitry, and introduces specific circuits for the armature control of dc motors, for the control of illumination intensity and heat, and for the control of bidirectional clutch systems or split-field generators. For those not familiar with the silicon controlled rectifier and the unijunction transistor, a brief rundown is given on the important characteristics of these new semiconductor devices.**

Once the silicon controlled rectifier (*SCR*) became a practical control system component, it was necessary to devise ways of firing the rectifier gate so that the device could be used as a power modulator. Several methods of gate control have been developed, and one of the better of these employs the unijunction transistor (*UJT*). The silicon controlled rectifier, in conjunction with the unijunction transistor, yields an all-semiconductor phase-controlled rectifier system that has many advantages in ac and dc machine drives and controls.

Both the silicon controlled rectifier and the unijunction transistor have been described in the literature (Refs. 1, 2, 3), but for those who are not familiar with them, brief discussions of these two basic devices are given on the following two pages.

## *What's needed in the firing circuit*

When the silicon controlled rectifier is used in a phase-controlled rectifier system, it is desirable that its firing circuits achieve most of the following:

1. Low power requirements and high efficiency.
2. Steep wavefront on firing signal to reduce effect of junction temperature change and of variations in individual controlled-rectifier characteristics.
3. Low standby current to prevent both undesired firing and an increase in reverse leakage current to the anode during the inverse part of the cycle.
4. Minimum heating effect of the gate signal on the controlled rectifier.
5. Firing angle independent of ambient temperature and supply voltage.
6. Pulse amplitude independent of firing angle.
7. Identical firing angles on both half-cycles in full-wave circuits.
8. Wide range of firing angles and operating frequencies.
9. Fast response time.
10. Adaptability to electrical feedback signals and to multiple inputs.
11. Electrical isolation between control and power circuits.
12. Simplicity, reliability, and small size.

Unijunction transistor firing circuitry meets all of these objectives with the exception of item 11; the circuits are not isolated when the control circuit is operated on dc feedback from the power circuit. In general, however, this limitation is not serious, since the control circuit will usually have a common lead with one side of the controlled-rectifier output.

## THE SILICON CONTROLLED RECTIFIER

Figure 1 shows a 16-amp 300-volt silicon controlled rectifier, its schematic symbol, and its terminal designations. Electrically, the controlled rectifier is the solid-state equivalent of a gas thyratron tube. With its anode negative with respect to the cathode, the rectifier exhibits a very high impedance, blocking the flow of current in the anode circuit. But even when the anode is positive, the controlled rectifier still blocks the flow of current until an appropriate firing signal is applied to the gate-cathode circuit. Within 1 to 3 microsec after this signal is applied, the rectifier switches to a high conductive state with a voltage drop in the order of 0.8 to 1.5 volts at rated load-current levels. With the controlled rectifier in its ON state, anode current is limited by the external circuit and is no longer subject to control by the gate. The rectifier reverts to its high-forward-resistance or blocking state only after anode current has been reduced to essentially zero for 10 to 20 microsec.

The firing characteristics of a typical line of 16-amp controlled rectifiers are shown in Figure 2. The inset indicates that the gate signal necessary to fire any cell of this type under the most adverse conditions (minus 65 deg C junction temperature) is 80 milliamp at 3 volts, or 240 milliwatts. This assumes either a dc level of this magnitude or a pulse of this magnitude with a duration of at least 6 microsec. For shorter pulses, the pulse amplitude necessary for firing varies inversely with pulse duration. Thus, a 3-microsec pulse should have an amplitude of at least 160 milliamps.

The shaded area in Figure 2 reveals the substantial range of firing points for this typical line of controlled rectifiers. While an 80-milliamp gate current may be required for firing at minus 65 deg C, only 25 milliamp suffices when the junction is at 125 deg C. In some cases, a signal as low as 0.25 volt on the gate may be sufficient for firing.

*FIG. 1. A—a 16-amp silicon controlled rectifier (GE Type C35); B—the arrangement of P-N junctions and electrodes in a controlled rectifier; C—the circuit symbol.*

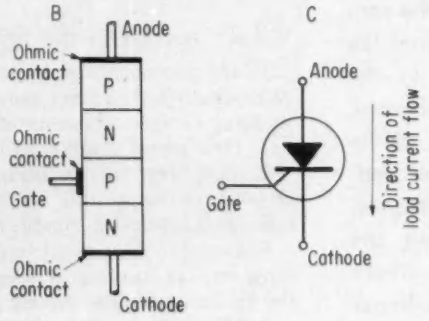
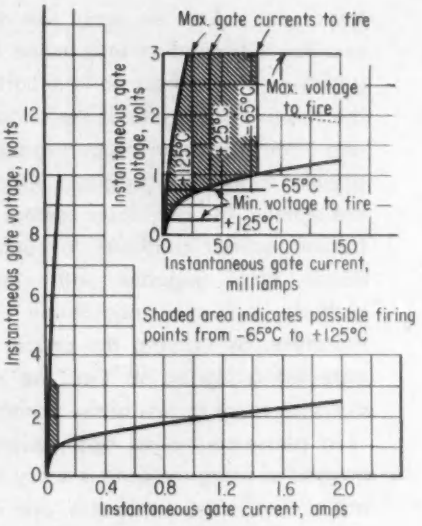



*FIG. 2. Firing characteristics of controlled rectifier shown in Figure 1A.*




## Developing the firing circuits

A simple sawtooth oscillator can be achieved by operating a unijunction transistor in its negative resistance region, Figure 5. Capacitor C will charge from the dc source at a rate depending on the RC time constant. When capacitor voltage reaches the peak-point emitter voltage the transistor will fire, discharging the capacitor through B1 in a sharp pulse of current. If resistor R is large enough to keep the unijunction transistor in its negative resistance region once the capacitor has discharged (2,000 to 3,000 ohms is adequate for this purpose), the transistor will then recover its blocking state and permit the capacitor to charge up for another cycle. The charging rate, and therefore the sawtooth frequency, can be adjusted by varying R.

Resistor r in series with B2 compensates for the variation of interbase resistance $R_{BB}$ and $V_D$ with temperature. For this fixed resistor to keep the peak emitter voltage $V_P$ constant over the operating temperature range, its value should be approximately

$$r \cong \frac{0.70\,R_{BB}}{\eta V_1} \qquad (2)$$

where $V_1$ is the dc supply voltage to the unijunction transistor circuit.

The current pulse through B1 during transistor conduction is ideal for firing a silicon controlled rectifier. Pulse duration is measured in microseconds and its amplitude can be adjusted from a few milliamperes to over 1 amp by properly selecting capacitor C and the external impedance between B1 and ground. By connecting the gate-cathode circuit of

## THE UNIJUNCTION TRANSISTOR

Figure 3A shows a typical silicon unijunction transistor, rated for 50 milliamps average current, 2-amp peak at 25 deg C. This device, too, has characteristics somewhat analogous to a gas thyratron, but its mode of operation is altogether different from the silicon controlled rectifier.

The unijunction transistor consists of an *N*-type silicon bar with electrodes on each end and a *P*-type emitter and junction slightly above center, Figure 3B. The electrical characteristic between *B*1 and *B*2 is that of a linear resistance, varying between 3,000 and 18,000 ohms, depending on type and temperature. In normal usage, a positive voltage $V_{BB}$ is applied to *B*2 with respect to *B*1. As long as the voltage on the emitter is less than the voltage adjacent to it in the *N*-region (as dictated by the linear gradient developed by $V_{BB}$), the *P-N* junction will be reverse-biased and only a leakage current in the order of a fraction of a microampere will flow in the emitter circuit. But when the emitter voltage $V_E$ reaches the level of the adjacent *N*-region, the junction becomes forward-biased, the resistance between emitter *E* and *B*1 decreases abruptly by the mechanism of conductivity modulation, and current flow from the emitter to *B*1 becomes almost entirely limited by the external impedance in the transistor circuit.

As soon as the unijunction transistor fires, the voltage drop between the emitter and *B*1 is determined by the characteristics shown in Figure 4. If sufficient emitter current flows so that operation continues on the right, or positive, resistance side of the indicated valley, the emitter will stay in conduction. But if the external circuit reduces the emitter current below the valley point, the transistor reverts to its high impedance or blocking state.

The emitter voltage at which the unijunction transistor fires is called the peak-point emitter voltage, $V_P$, and can be determined from

$$V_P = \eta V_{BB} - V_D \qquad (1)$$

where $\eta$ is the intrinsic standoff ratio of the transistor (constant for a given device), $V_{BB}$ is the applied interbase voltage, and $V_D$ is about 0.7 volt.

*FIG. 4. Static emitter characteristics of unijunction transistor shown in Figure 3A at 25 deg C.*

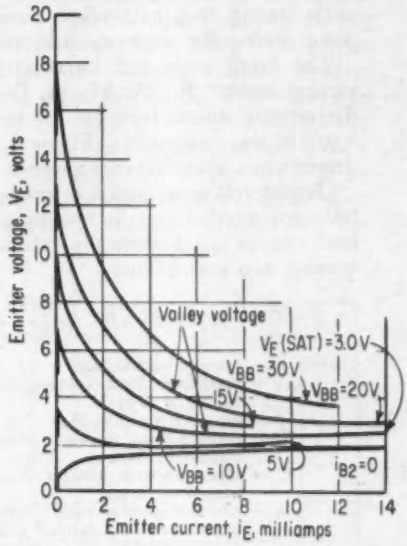
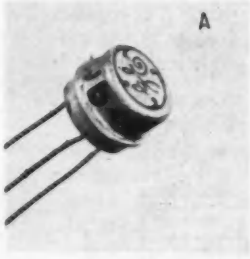
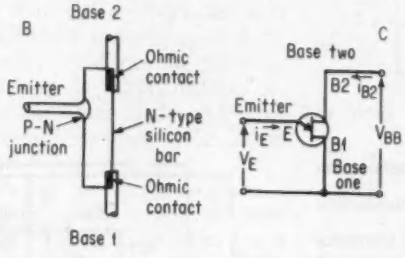



*FIG. 3. A—a unijunction transistor (GE Type 2N492); B—the internal construction of a unijunction transistor; C—the circuit symbol.*




the controlled rectifiers between *B*1 and ground (as shown in Figure 6), the unijunction transistor current pulse will be of the proper polarity to fire one or more controlled rectifiers.

Using typical rectifiers and a 0.2 mfd capacitor in the transistor emitter circuit, a 4-volt pulse of approximately 30 to 40 microsec duration is produced between *B*1 and ground. A 50-ohm resistor connected in shunt with the controlled-rectifier gate circuits prevents rectifier misfiring due to high unijunction transistor interbase current (up to 5 to 10 milliamps at very low temperatures).

### *Synchronizing firing with the anode supply*

If the basic unijunction transistor oscillator circuit is to provide a properly phased firing signal for the controlled rectifier, it must be synchronized with the frequency of the main line voltage. The full-wave center-tapped phase-controlled rectifier shown in Figure 6 provides for this synchronization. In this instance, *SCR*1 and *SCR*2 are both fired by *UJT-Q*2.

Transistor *Q*1 and diodes *D*1, *D*2, *D*3, and *D*4 synchronize the unijunction transistor timing cycle with the respective anode voltages of *SCR*1 and *SCR*2. Whenever the anode of either *SCR*1 or *SCR*2 swings positive with respect to the common cathodes, *D*3 blocks the current flow and cuts off transistor *Q*1, permitting capacitor *C* to charge and, in turn, permitting the unijunction transistor to fire whichever controlled rectifier has the positive anode. As soon as the controlled rectifier has fired, its anode voltage drops to the conduction value of about 1 volt. From this point to the end of the

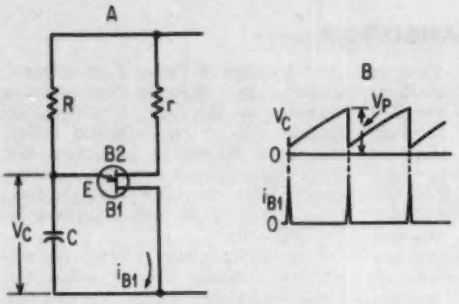



*FIG. 5. A—basic relaxation oscillator circuit using unijunction transistor; B—voltage and current waveforms.*

half-cycle, transistor *Q*1 clamps emitter *E* of the unijunction transistor to the conduction value of the anode voltage, preventing *UJT*-*Q*2 from firing again during that half-cycle. Similar action takes place during the alternate half-cycle.

The firing angle can be adjusted manually by varying resistor *R*. At 60 cps, the firing angle of the circuits shown here can be varied from about 8 to 180 deg (fully off). Figure 7 shows the waveshapes when operating into a resistive load.

Output voltage variation in single-phase half- and full-wave rectifier circuits operating into a resistive load can be mathematically related to *R*, *C*, frequency, and $\eta$ as follows:

$$\frac{e_o}{e_{max}} = \tfrac{1}{2}\left[\cos\left(2\pi fRC \ln \frac{1}{1-\eta}\right) + 1\right] \qquad (3)$$

where $e_o$ = average load voltage
$e_{max}$ = maximum load voltage, assuming firing at beginning of cycle.
$f$ = supply frequency, cps
$R$ = resistance in emitter circuit of unijunction transistor, ohms
$C$ = capacitance in emitter circuit of unijunction transistor, farads
$\eta$ = effective standoff ratio of unijunction transistor (equals intrinsic standoff ratio if temperature is compensated by proper resistor *r*)

This equation is valid if the following assumptions are made: the synchronizing circuit ceases to divert charging current from *C* the instant the anode voltage of a controlled rectifier swings positive through zero; once the capacitor starts to charge there are no leakage paths through the emitter of the unijunction transistor or through the synchronizing circuit that will affect its charging rate; the controlled rectifiers are perfect switches, with infinite forward and reverse resistance before firing, and zero forward resistance after firing; and the unijunction transistor is temperature-compensated by the proper selection of resistor *r* in the *B*2 circuit.

Note that the output voltage of the circuit of Figure 6 is essentially independent of the dc supply voltage to the unijunction transistor. Variations in this supply voltage affect both the charging rate to capacitor *C* and the interbase voltage, while the interbase voltage, in turn, determines the peak-point emitter voltage. These two effects compensate for one another and the firing angle remains constant for gradual shifts in supply voltage.

## *Shunt control of firing angle*

Phase-angle control of the circuit in Figure 6 can be secured by varying *R*, *C*, or frequency in the unijunction transistor circuit. This type of control can be used where manual setting of a potentiometer, for example, is satisfactory, though it is usually desirable to shift phase automatically in accordance with low-level electrical signals such as those developed by feedback networks.

Figure 8 shows one way of electrically controlling phase angle while substantially increasing circuit gain. In this case, an *NPN* transistor, *Q*3, is connected in shunt with emitter capacitor *C*. With this transistor cut off ($i_B$ equals 0), the charging rate to capacitor *C* and the firing angle of the unijunction transistor are influenced only by the *RC* time constant and the characteristics of the unijunction transistor (as in the previous circuit). But with a positive signal on the base of *Q*3, charging current to capacitor *C* is diverted through the collector of *Q*3 at a maximum rate of $\beta i_B$, where $\beta$ is the grounded emitter current gain of the transistor. Then as more current is diverted from *C*, it requires longer to reach the emitter firing voltage of the unijunction transistor and the firing angle is retarded.

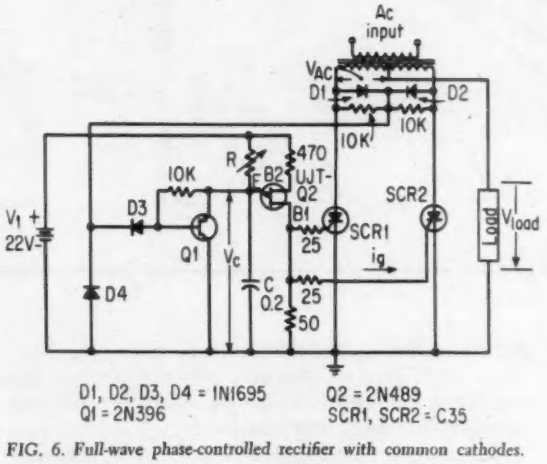



*FIG. 6. Full-wave phase-controlled rectifier with common cathodes.*

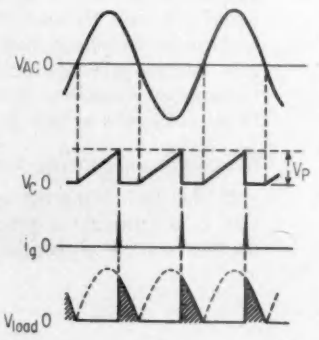



*FIG. 7. Voltage waveforms and current waveforms of circuit in Figure 6.*

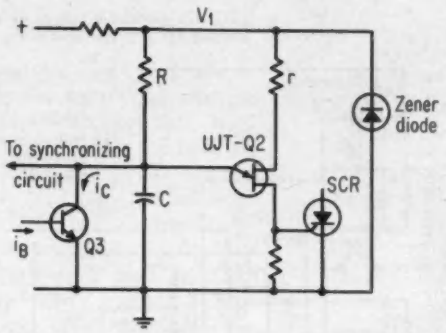



*FIG. 8. Shunt-transistor control of unijunction transistor firing angle.*

The output voltage of controlled rectifier single-phase supplies using this type of control and operating into resistive loads can be expressed as follows:

$$\frac{e_o}{e_{max}} = \tfrac{1}{2}\left\{\cos\left[\frac{2\pi fRC}{1+Rh_{ob}\beta} \times \ln\frac{V_1-\beta i_B R}{(V_1-\beta i_B R)-\eta V_1(1+Rh_{ob}\beta)}\right]+1\right\} \quad (4)$$

where $\beta$ = grounded emitter current gain of transistor $Q3$ for level of collector current being considered.
$h_{ob}$ = output admittance of transistor $Q3$, mhos
$V_1$ = dc supply voltage to $UJT$ circuit
$i_B$ = base current in $Q3$

For this equation to be valid, the same assumptions are required that were made for Equation 3 plus this additional one: the current gain of transistor Q3 is constant with variations in collector voltage. In this circuit, the dc supply voltage $V_1$ has a pronounced effect on firing angle and must be regulated for good circuit stability. The Zener regulating diode of Figure 8 does this.

Maximum output from this circuit occurs when $i_B$ equals 0, since no charging current is diverted from capacitor C under this condition. The other point of interest is the value of $i_B$ at which the unijunction transistor will fail to fire; at this value there is zero output voltage across the load. The approximate value of $i_B$ for this condition is as follows:

$$i_B \cong \frac{V_1}{\beta R}(1-\eta) \text{ if } \frac{1}{2fRC} > 4 \text{ and } Rh_{ob}\beta \ll 1 \quad (5)$$

This circuit has a very high gain, and displays an abrupt change from maximum output to zero output for a small change in base current $i_B$. Figure 9 shows the control characteristic of the full-wave voltage regulating bridge of Figure 10. With a 117-vac supply, the maximum output rating of this circuit, using two C35 controlled rectifiers, is 32 amps, or over 3.5 kw when working into a resistive load. A variation of less than 3 microamps in $i_B$ is sufficient to regulate this load over essentially its full range. Power gains of $10^8$ are readily attainable.

## How to use these basic circuits

The foregoing covered controlled rectifier circuits with common cathodes; the same general approach can be used with common anodes, Figure 11. Because the cathodes and gates of the respective silicon controlled rectifiers must be electrically isolated from each other, a small transformer with multiple secondaries is introduced between B1 of the unijunction transistor and ground. The secondaries are connected to the gate and cathode terminals of the respective controlled rectifiers. The unijunction transistor emitter capacitor is free to charge up whenever either anode is more positive than 3 volts with respect to its cathode. Since forward voltage drop of the rectifier during conduction is less than 3 volts, transistor Q4 will clamp the voltage on C after firing, just as in the common cathode circuits.

### *Armature control of dc motors*

A full-wave reversing control can be achieved by combining the common anode and common cathode circuits. Figure 12 shows a circuit of this type suitable for armature-controlling a dc motor. Whenever *UJT-Q1* fires *SCR2* and *SCR3*, positive polarity voltage is impressed on the right-hand side of the load. In turn, when *UJT-Q3* fires *SCR1* and *SCR4*, the polarity on the load is reversed. Potentiometer R1 is selected so that neither *UJT-Q1* or *UJT-Q3* fires within its respective half-cycle when this pot is centered. Thus, none of the controlled

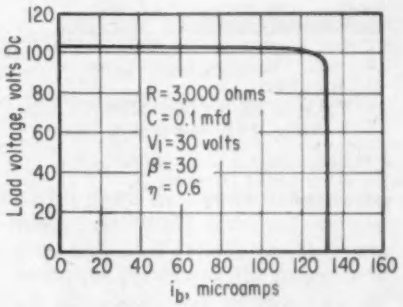
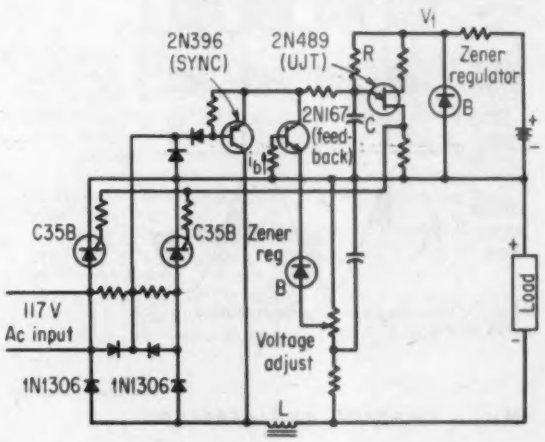



*FIG. 9. Sharp control characteristic of voltage regulating circuit shown in Figure 10.*

*FIG. 10. Dc voltage regulator using phase-angle control of single-phase rectifier bridge.*



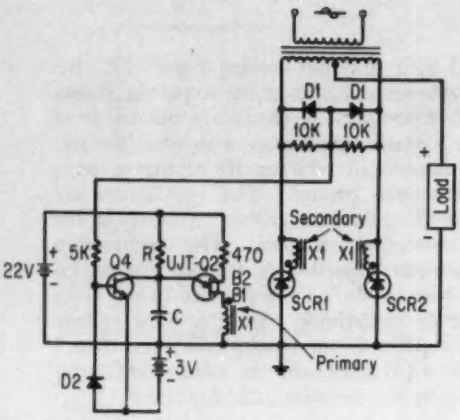
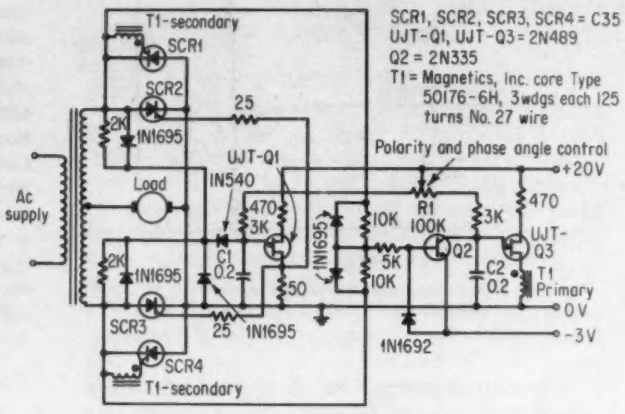
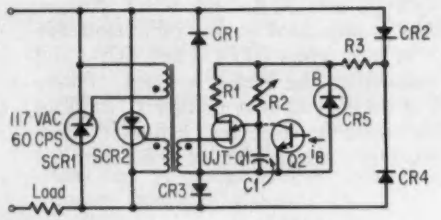



*FIG. 11. Full-wave phase-controlled rectifier circuit with common anodes.*

*FIG. 12. Adjustable voltage dc reversing drive, suitable for armature controlling a dc motor.*




R1 = 390 ohms
R2 = 100,000-ohm linear pot
R3 = 3,300 ohms, 5 watt
C1 = 0.2 MFD
SCR1, SCR2 = C35B
CR1, CR2, CR3, CR4 = 1N1695
CR5 = 1N1527 Zener diode, 1 watt, 22 volts
UJT-Q1 = 2N489
T1 = Magnetics, Inc, core, Type 50176-6H, 3 windings, 125 turns each of No. 27 wire

*FIG. 13. Phase-controlled ac switch for lamp dimming or heater control. Transistor Q2 can be used for feedback control of phase angle.*

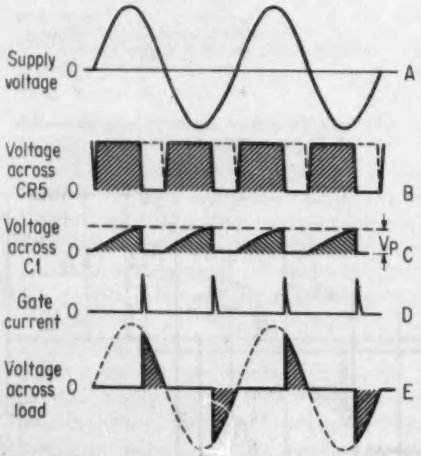



*FIG. 14. Waveshapes in ac phase-controlled switch of Figure 13.*

rectifiers fires and no voltage appears across the load. But if the potentiometer arm is moved to the left, the charging rate to C1 in the emitter circuit of UJT-Q1 increases until UJT-Q1 begins to fire SCR2 and SCR3 near the end of their respective half-cycles. Maximum output voltage occurs when R1 is reduced to a minimum on the left. Similar action occurs if the R1 wiper is moved to the right, except that voltage of the opposite polarity is impressed on the load. Electrical feedback control of motor voltage can be introduced by using shunt-transistor control as shown in Figure 8.

When driving a dc motor, this supply provides plugging action if the control potentiometer is abruptly reversed. Note that when feeding counter emf loads there is no possibility of firing before the anode is positive, as might occur with systems synchronized to the main ac line instead of to the controlled rectifier anodes. By synchronizing to the anode potential, firing can occur only after an anode has swung positive.

## *Control of illumination intensity and heat*

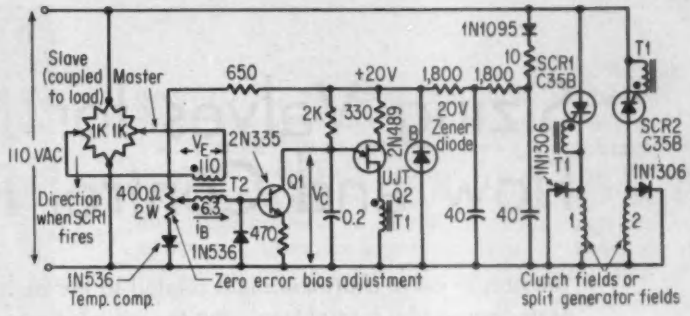
Figure 13 shows a phase-controlled ac switch that has been used for illumination-intensity and heat control. This circuit draws on the voltage developed across the controlled rectifiers for unijunction transistor interbase supply and synchronization, thereby eliminating the dc power supply and synchronizing transistor used in the preceding circuits.

The firing circuit is connected to the output of a single-phase bridge formed by diodes CR1, CR2, CR3, and CR4. Through the action of these diodes, plus Zener regulating diode CR5 and resistor R3, a clipped and rectified voltage with the waveform shown in Figure 14B is applied to the unijunction transistor and its emitter circuit. The level at which the voltage is clipped is determined by the avalanche voltage of CR5.

This voltage charges C1 through R2 to fire the

unijunction transistor and whichever controlled rectifier has positive anode voltage during that half-cycle, as shown in Figure 14C, D, and E. After firing, the voltage across the silicon controlled rectifiers decreases to the conduction value of approximately 1 volt. This keeps capacitor C1 discharged until supply voltage reverses; then a new timing cycle starts for the alternate controlled rectifier.

Potentiometer R2 controls the firing angle of both controlled rectifiers, and minimum output occurs with R2 in its maximum position. At this setting the voltage across C1 cannot reach the peak emitter voltage $V_P$ before the line voltage reverses. As the unijunction transistor interbase voltage dips momentarily to zero during this reversal, the transistor fires in accordance with the relation of Equation 1, discharging C1 in preparation for the next half-cycle. At this minimum output setting, the controlled rectifiers conduct for only a very brief interval at the end of each half-cycle, developing less than 1 percent of full voltage across the load. For electrical control of the firing angle, an *NPN* transistor, Q2, can be connected in shunt with C1 as shown in Figure 13. R2 should then be fixed at a value of approximately 2,500 ohms.




T2 = 110V/6.3V, 0.6A transformer
T1 = Magnetics Inc, Type 50176-6H, pri = 125T, sec = 100T each

*FIG. 15. A half-wave position servo for controlling excitation to clutch fields or split generator fields.*

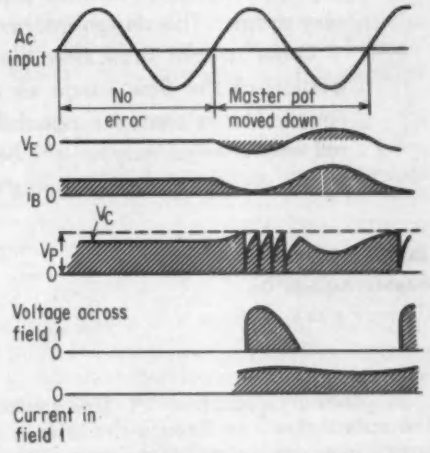



*FIG. 16. Waveshapes in position servo of Figure 15.*

## *Servo control of split-field generator or bidirectional clutches*

Figure 15 shows how controlled rectifiers are used in a relatively simple but highly reliable and compact servomechanism. Controlled rectifiers SCR1 and SCR2 deliver power to the respective fields of a split-field generator, or to one or the other fields of a pair of magnetic clutches. Which field is excited depends on the direction of slave potentiometer displacement from the position of the master. The 1N1306 free-wheeling rectifier across each field assures continuous dc through the field being excited.

The voltage and current waveforms in this circuit are shown in Figure 16. The first cycle represents the condition when the arms of the master and slave potentiometers are in the same position. Here, no ac error voltage appears between the two arms and Q1 is biased by $i_B$ so that voltage $V_C$ on the emitter of *UJT*-Q2 is slightly less than that necessary to fire the unijunction transistor. Neither SCR1 nor SCR2 conducts under these conditions.

If the master arm is moved down, voltage $V_E$ develops between the arms of the slave and master pots, as shown in the second cycle of Figure 16. The polarity of $V_E$ is such that $i_B$ is reduced while the anode of SCR1 is positive, and increased when the anode of SCR2 is positive. Thus, $V_C$ increases and fires *UJT*-Q2 and SCR1 during the half-cycle that the anode of SCR1 is positive. $V_C$ decreases during the alternate half-cycle, further preventing SCR2 from firing. As SCR1 fires and initiates movement in the mechanical system, the slave arm moves down toward the position of the master arm. As it approaches the equilibrium position, $V_E$ decreases and the firing angle increases to 180 deg. At this point the system comes to rest.

If the master pot arm is displaced upward, the system behaves in a similar manner except that SCR2 and its field are excited instead of SCR1.

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2. *DESIGN FUNDAMENTALS OF UNIJUNCTION TRANSISTOR RELAXATION OSCILLATORS*, T. P. Sylvan, "Electronic Equipment", December 1957.
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# Sizing Valves for Maximum Flow and Control Rangeability

**The proper valve characteristic is related to the desired static and dynamic performance of a control loop. But the actual characteristic, whether linear, equal-percentage, or square-root, depends on the piping in the system. In this, his third article on valves (see Refs. 1 and 2), the author presents an analytical method for selecting valve size that depends on normal and expected maximum flow, on piping resistance, and on valve and line pressure drops. This design information is summarized in graphical form.**

**Other graphs show how the ideal characteristic is maintained over a portion of the flow range as a function of valve-to-piping conductance ratio. This is control rangeability. From these graphs, the designer can tell what changes may have to be made—perhaps a larger valve or pump—to assure desired control rangeability.**

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In practical applications of flow control valves, the normal flow rate through the valve is generally known from steady-state processing conditions. Maximum flow rate, however, which determines valve size, depends primarily on the magnitude of the deviation from normal flow needed to counteract a disturbance, and also on such factors as expected fouling of valve and pipes or future increase in normal flow due to increased plant throughput. Desired minimum flow usually raises no problems, except where leakage flow in the closed position is too large.

At normal flow in a valve-plus-line combination, with given $C_v/C_l$ ratio, the valve will be in some position between fully open ($A = 1$) and fully closed ($A = 0$), so that the actual $C_v$ factor at normal flow is $AC_v$. There will be some pressure drop ($\Delta P_l$) across the piping and across the valve ($\Delta P_v$), with the total pressure drop ($\Delta P_{tot}$) being constant. The ratio $\Delta P_v/\Delta P_l$ is important in designing flow control systems.

Under normal flow conditions where $0<A<1$, the flow is given by:

$$F_{norm} = \left[\frac{1}{(1/AC_v)^2_{norm} + (1/C_l)^2}\right]^{1/2} [\Delta P_{tot}]^{1/2} \qquad (1)$$

When $A = 1$, the flow will be maximum:

$$F_{max} = \left[\frac{1}{(1/C_v)^2 + (1/C_l)^2}\right]^{1/2} [\Delta P_{tot}]^{1/2} \qquad (2)$$

Taking the ratio of these two equations gives the relationship of the maximum flow to normal flow:

$$\frac{F_{max}}{F_{norm}} = \left[\frac{1 + (\Delta P_v/\Delta P_l)_{norm}}{1 + (C_l/C_v)^2}\right]^{1/2} \qquad (3)$$

where: $$(\Delta P_v/\Delta P_l)_{norm} = (C_l/AC_v)^2_{norm} \qquad (4)$$

The benefits from using Equation 3 for sizing control valves (that is, for choosing the valve's $C_v$ factor) are more easily seen when a family of curves derived from the equation is plotted, as in Figure 1. (This figure also contains a plot of $(AC_v/C_l)_{norm}$ as a function of $(\Delta P_v/\Delta P_l)_{norm}$.)

A great deal of useful information can be extracted from Figure 1. For instance, the maximum possible flow would occur in the theoretical case of the valve being removed from the system. That is, when $C_v/C_l = \infty$, and the denominator under the square-root sign in Equation 3 therefore equals unity. Furthermore, the plot also indicates that $C_v/C_l$ ratios of 4 or 5 give just about the same maximum flow as when the ratio is infinity. However, using such large $C_v/C_l$ ratios distorts the linear or equal-percentage characteristic of the valve-plus-piping combination, as pointed out in Ref. 2. Another point of interest is that for $(\Delta P_v/\Delta P_l)_{norm} < 0.5$, the maximum flow never can be larger than about 1.2 times the normal flow, indicating that the pressure-drop ratio should be kept fairly large.

Figure 1 serves as a handy guide for finding $C_v/C_l$, $F_{max}/F_{norm}$, or $(\Delta P_v/\Delta P_l)_{norm}$ when any two factors are known or assumed. For example, under normal flow conditions $(\Delta P_v/\Delta P_l)_{norm} = 4$, and the maximum flow is twice normal flow ($F_{max}/F_{norm} = 2$); then, from the family of curves, $C_v/C_l = 2$. The actual valve size $C_v$ for obtaining the desired maximum flow is thus determined, provided the conductance factor of the piping, $C_l$, is known.

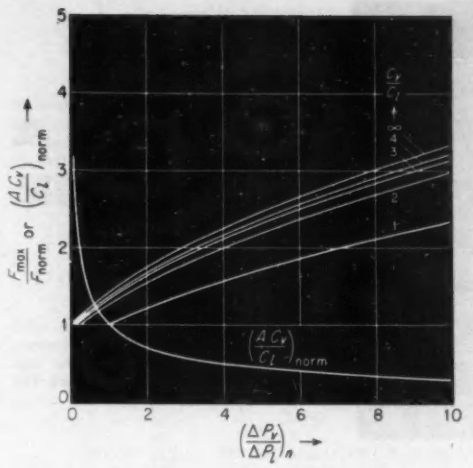



*FIG. 1. Design curves for finding valve size, pressure drops across valve and piping, maximum flow, and valve stem position.*

The valve stem positions S can be determined for normal flow conditions from the plot of $(AC_v/C_l)_{norm}$ vs. $(\Delta P_v/\Delta P_l)_{norm}$. In the preceding example $(AC_v/C_l)_{norm} = 0.5$; therefore, $A = 0.5 \times 0.5 = 0.25$. Assuming a linear valve, that is, $A = S$, the stem position is 25 percent open. For an equal-percentage valve with 2-percent leakage, the stem position can be found from $A = 0.02\ (50)^S$, or $S = (\log A/0.02)/(\log 50)$. In this case, the stem position is 65-percent open.

## Rangeability

A valve controls one of the process variables by adjusting one of the process flows. It is a well-known fact that good control is possible over only a limited change in flow. This practical limitation can sometimes interfere with good control.

Through the years attempts have been made to define the ability of the valve to manipulate the flow. The term mostly used is *rangeability*. This definition varies considerably: there is *valve rangeability* of the valve only; *flow rangeability* of the valve plus piping; and *control rangeability*.

*Valve rangeability*—The common definition of valve rangeability $R_v$ is the ratio of maximum flow to leakage flow, both at the same pressure drop across the valve. This means that a valve with 2-percent leakage has a valve rangeability of 50 to 1; this rangeability is an inherent property of the valve.

*Flow rangeability*—Sometimes rangeability is used in relation to the valve-line combination, so that flow rangeability $R_f$ is the ratio of maximum flow to leakage flow, both at the same $\Delta P_{tot}$ across the flow circuit. As the $C_v/C_l$ ratio increases $R_f$ decreases. This is shown in Figure 2 for a valve with a 2-percent leakage at constant pressure drop.

*Control rangeability*—Neither valve rangeability nor flow rangeability takes into account what happens to the (linear or equal-percentage) characteristic, which can affect both static and dynamic control. A more flexible definition is that of control rangeability $R_c$: the change in flow that can be obtained, while maintaining a certain characteristic of a valve-plus-line combination within a given accuracy.

Control rangeability depends not only on the valve-line combination, but also on the part of the flow range used and on the fidelity with which the square-root, linear, or equal-percentage character is maintained over the selected part of the full flow range. The fidelity required may vary widely, depending on engineering judgment; nevertheless, control rangeability as defined is very useful, because the magnitude of expected disturbances determines its minimum value. The smaller the control rangeability needs to be, the less the actual valve-plus-line characteristic has to satisfy the ideal. The best compromise must be found between good performance—a stable, yet fast loop under all conditions—and the smallest valve size—the least amount of dollars.

Consider control rangeability in more detail. To obtain good static and dynamic control for a given process, a linear, equal-percentage, or square-root characteristic is selected (see Ref. 1). But to counteract disturbances the flow must vary between A and B gpm. It is only over the flow range between A and B gpm that the flow characteristic must be maintained. What happens to the characteristic outside range A and B is of no concern. As shown in Ref. 2, linear and equal-percentage valves, together with piping, maintain their linear or equal-percentage characteristic over the full flow range for small values of $C_v/C_l$. For larger $C_v/C_l$ ratios, the characteristics lose their ideal shape over the full flow range; but even so, some portion of the ideal characteristic is maintained over part of the flow range.

The preceding points are brought out more clearly in Figures 3 through 6. A characteristic is linear when $\%F_{max}/\%S$ is constant; exponential when $\%F/\%S$ is constant; and square-root when $\%F_{max}{}^2/F/\%S$ is constant. The foregoing ratios will be called measures of constancy. The actual value of the ratio only influences the static gain,

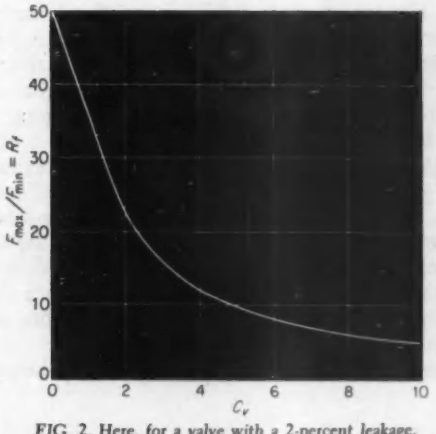



*FIG. 2. Here, for a valve with a 2-percent leakage, the rangeability of the valve itself $(C_v/C_l = 0)$ is 50, but as piping is added to the system the flow rangeability of the same valve decreases rapidly.*

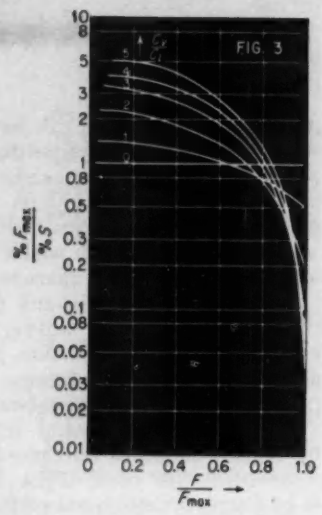



*FIG. 3. The linear valve maintains its linear characteristic, even with piping in the system, over the part of the full flow range at which the curves are essentially constant or zero slope.*

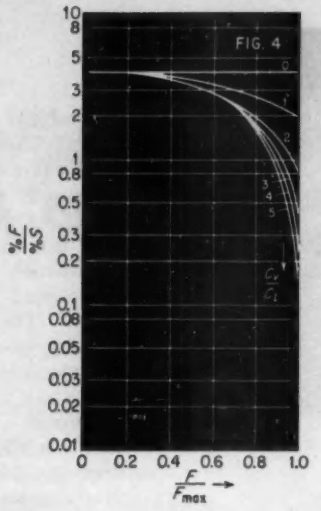



*FIG. 4. The equal percentage valve maintains its exponential characteristic, even with piping, over the part of the full flow range at which the curves are essentially constant.*

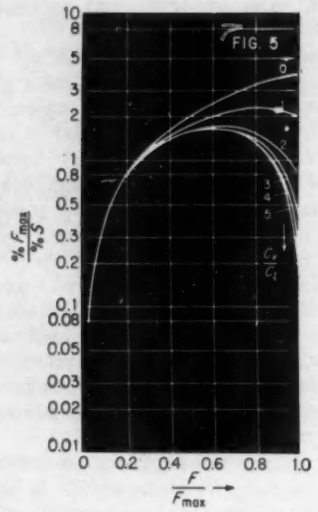



*FIG. 5. In the part of the full flow range in which the curves are essentially constant, the equal-percentage valve provides a linear characteristic.*

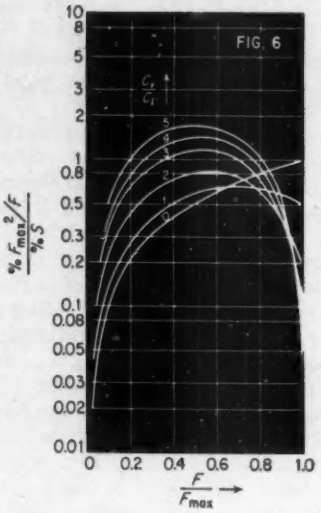



*FIG. 6. In the part of the full flow range in which the curves are essentially constant, the linear valve provides a square-root characteristic.*

which can be compensated for by the controller's proportional band setting.

In Figure 3, the linear valve has a linear characteristic for $C_v/C_l = 0$; but for larger $C_v/C_l$ ratios the total characteristic rapidly becomes nonlinear. Over the lower part of the flow range the linearity is fairly well maintained for all $C_v/C_l$ ratios. A similar situation obtains for the equal-percentage valve, Figure 4; here the graphs check the exponential character of an equal-percentage valve plus piping over the full flow range of various $C_v/C_l$ ratios. Figure 4 shows, for instance, that to maintain an exponential characteristic of the flow range used, either $\Delta P_{tot}$ has to be increased to increase $F_{max}$ and hence decrease the $F/F_{max}$ ratio; or the valve size has to be increased to decrease the $C_v/C_l$ ratio. Now economic considerations enter the picture, since maintaining the exponential character calls either for a larger pump or a larger valve.

Figure 5, on the other hand, shows that the equal-percentage valve can provide a linear characteristic over the middle and/or upper part of its flow range. This also applies to the linear valve when used for a square-root characteristic, as shown in Figure 6.

Between what boundaries a certain characteristic is to be maintained depends on the application. If the application is critical, allow about a 10-percent difference between maximum and minimum values of the measure of constancy. In normal applications, allow a factor of 200 percent between maximum and minimum. For noncritical applications the factor can go even higher. The logarithmic scales of Figures 3 through 6 help in selecting the best part of the flow range for obtaining the desired characteristic, including its deviation from ideal.

## REFERENCES

1. A *FRESH LOOK AT SELECTING CONTROL VALVE CHARACTERISTICS*, J. E. Valstar, "Control Engineering", March 1959, pp. 103-108.
2. *HOW PIPING INFLUENCES VALVE PERFORMANCE*, J. E. Valstar, "Control Engineering", April 1959, pp. 123-125.

# A Graphical Way to Solve Nonlinear Circuits

W. R. EVANS and
D. H. MITCHELL
Autonetics

*Nonlinear circuits can be solved quite simply by a graphical method similar to that used for plotting a load line and finding the operating point on vacuum tube characteristics. This powerful method works well for any kind of system: electrical, mechanical, magnetic, hydraulic, thermodynamic, etc. It is illustrated here by solution of several resistive electrical networks of increasing complexity.*

*In Figure 1, a voltage $V_o$ is applied across two resistors in series, one of them nonlinear with respect to voltage. The following conditions must exist:*

$$V_1 + V_2 = V_o, \qquad I_1 = I_2 = I$$

*A graphical solution is simplest, and the graph must show the relationships above. First plot the V-I characteristic of one element normally; i.e., with increasing voltage and current plotted to the right and upward from the origin. Then plot the V-I characteristic of the second to the same scale with the voltage reversed (to the left) and the ampere scale in the same direction as the first. The second plot is located on the first so that its origin is at the applied voltage, $V_o$, on the first plot. The intersection of the two curves gives the values of $V_1$, $V_2$, and I, which satisfy the two equations. These values can be read easily from the graph.*

*Note that the general solution for any applied voltage can be found by plotting the second curve on a piece of transparent paper and sliding its origin along the voltage scale of the first. For a constant applied voltage, however, it is easier to draw the second curve directly on the first.*

FIG. 1

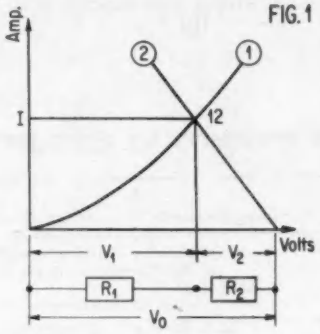
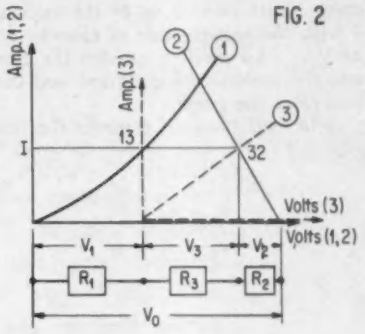



FIG. 2




*Note also that the method would work just as easily if both resistors in Figure 1 were nonlinear.*

*Figure 2 shows a graphical solution for three resistors in series. In this case the characteristic of the third resistor must be plotted on transparent paper. The equations to be satisfied are:*

$$V_1 + V_2 + V_3 = V_o$$
$$I_1 = I_2 = I_3 = I$$

*These equations can be satisfied by sliding the plot of element 3 horizontally to the position where the intersection of the current scale of curve 3 with curve 1 has the same value as the intersection of curves 2 and 3.*

*Note that for multiple resistors in series, all the curves are drawn normally except the last, which is reversed. The curves must then be slid until the intersection of the current scale on each with the previous curve has the same value as the intersection of the final two curves. As before, the voltage and current values thus obtained satisfy the equations.*

FIG. 3

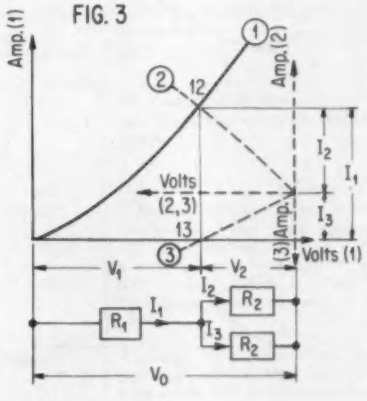


Figure 3 shows how the technique can be used to solve series-parallel networks. The conditions are:

$$I = I_1 = I_2 + I_3$$
$$V_0 = V_1 + V_3$$
$$V_2 = V_3$$

The method calls for plotting elements 2 and 3 with a common voltage scale and with their current scales in opposite directions. The current scale is then placed at $V_0$ on plot 1 and moved vertically until the same voltage is indicated by the intersection of curve 2 with curve 1, as by the intersection of curve 3 with the voltage scale of element 1; i.e., until $V_2 = V_1$. This position satisfies the three conditions, and the various voltage drops and currents can be read from the graph.

As a final example, consider the bridge circuit in Figure 4A. For this circuit, the conditions are:

$$V_1 + V_2 = V_3 + V_4 = V_0$$
$$V_2 = V_5 + V_4$$
$$V_3 = V_5 + V_1$$
$$I_1 = I_2 + I_5$$
$$I_4 = I_3 + I_5$$

The characteristic curves are plotted on three sheets of paper (two transparent), with those on a "common side" (i.e., 1 and 2, 3 and 4) plotted together, as in Figure 4 (B, C, and D). The sheets are then superimposed (Figure 4E) so that the origin of D is at $V_0$ on C, and is slid up and down at this voltage. The characteristic of element 5, sheet B, is moved with its origin on curve 2.

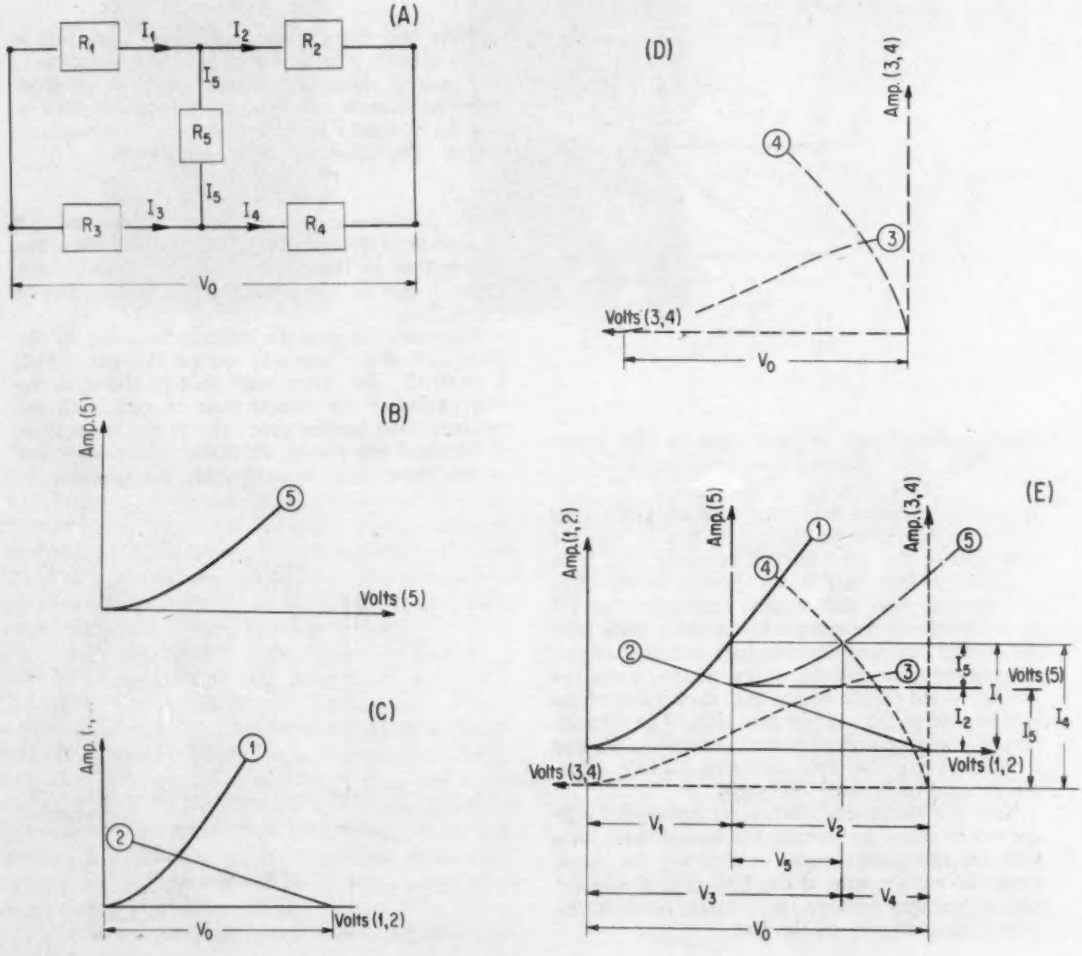
The two overlays, B and D, are then moved by trial and error until a rectangle is formed as in Figure 4E by the following four intersections:

1—Curves 4 and 5
2—Curve 3 and the horizontal scale of 5
3—The origin of 5 (on curve 2)
4—Curve 1 and the vertical scale of 5

At these positions the five equations are satisfied and the various voltages and currents can be read as shown.

Note that the nonlinearity of four of the five resistors used in this last example did not complicate the solution at all.

FIG. 4



# Control System Test Equipment

## PART II: COMPLETE TEST AND EVALUATION SYSTEMS

ABRAHAM M. FUCHS, Boonshaft & Fuchs, Inc.

**Specialized equipment for testing control systems divides into three classes: 1) devices that only generate a test signal, 2) systems that generate a test signal and also evaluate control system response, and 3) devices that only evaluate control system response. The first article in this series covered the first class—signal generators (see CtE, March 1959, page 116). This article describes nine complete testing systems, capable of both signal generation and response evaluation. The final article, to treat evaluation equipment, will appear in a future issue.**

### CHARACTERISTICS OF COMPLETE TEST AND EVALUATION SYSTEMS

| Manufacturer | Designation | Frequency range | Test signals | Cost | Remarks |
|---|---|---|---|---|---|
| Taylor Instrument Cos.<br>95 Ames Street<br>Rochester 1, N. Y. | Pneumatic Sine-Wave Generator | 0.0000362 to 0.739 cps | Pneumatic<br>3 to 15 psi;<br>sine and step | $3,500 | Result recorded on synchronized recorder |
| Servo Corp. of America<br>20–22 Jericho Tnpk.<br>New Hyde Park, N. Y. | Servoscope—Series 1100 | 0.005 to 100 cps (in five ranges) | Sine and step; suppressed-carrier and dc (sawtooth) | $1,390–$1,950 ($1,135 for cathode-ray indicator) | Fast and accurate phase measurement on oscilloscope |
| Industrial Control Co.<br>805 Albin Ave.<br>Lindenhurst, N. Y. | Model 100-A Dynamic Analyzer | 0.5" to" 50 cps | Sine and step; suppressed-carrier (sawtooth) | $820 | Simply and easily modified to meet special requirements |
| | Model 101-A Servo Tester | Step test at 0.2-, 1-, and 5-sec intervals | Dc and carrier | $960 | Compares transient response to preset overlay for production testing |
| Industrial Products Group<br>Minneapolis-Honeywell Reg. Co.<br>Wayne & Windrim Aves.<br>Philadelphia 44, Pa. | Servo Analyzer | 1 cycle per hour to 10 cps | Pneumatic; dc and carrier | $3,500 | Sampling method of frequency response measurement |
| Solartron, Inc.<br>530–532 Cooper St.<br>Camden 2, N. J. | Transfer Function Analyzer (O.S. 103A LFDO and VP253.2A LFRCI) | 0.5 cps to 1,000 cps | Suppressed carrier | $5,500 | Noise and quadrature rejection very high; 0- and 90-deg components are displayed |
| | JX 563A—Servo Test Set | 0.5 to 50 cps | Suppressed carrier | $2,097 | Production test unit; four test points; set tolerance on 0- and 90-deg components; high noise rejection |
| Short Brothers & Harland, Ltd.<br>208a Regent St.<br>London, W.I., England | Control System Analyzer | 0.01 to 109.9 cps | Sine, step, and ramp | 995£ | High harmonic and dc rejection; 0 and 90 deg components are read |
| Boonshaft & Fuchs, Inc.<br>994 Byberry Rd.<br>Huntingdon Valley, Pa. | Feedback Control System Analyzer | 0.05 to 200 cps | Sine | $4,000 | Amplitude and phase read directly; high noise rejection; manufactured under license from Shell Development Co. |

The nine complete testing systems described in this article include equipment for generating the disturbance test signals, and for evaluating control system response to these test signals. Thus, they do not generally require any additional equipment to perform complete frequency response (and sometimes step response) tests. For convenience, the table summarizes the important characteristics of these systems. Note that the major emphasis is on testing control systems with electrical inputs and outputs, although two sets of apparatus are specifically designed to yield pneumatic test signals.

Even though auxiliary oscilloscopes or recorders may be required with some, these systems are still qualified as complete servo test equipments. Thus, the Minneapolis-Honeywell Type BA-101 (covered as a signal generator in Part I of this series) may be said to belong to class two as well as to class one. It does have a variable-phase output that could be used for phase measurement with a Lissajous pattern.

While most of the discussion is on phase measurement, determination of amplitude ratio is apparent in all cases where control output is displayed. It should also be mentioned that most of these units are available with modifications to meet the special needs of unusual control system measurement problems.

## 1. TAYLOR PNEUMATIC SINE-WAVE GENERATOR

Intended primarily for testing process control systems, the pneumatic sine-wave generator has four functional parts: 1) the mechanical generator, 2) the mechanical-to-pneumatic signal converter, 3) two amplifiers, and 4) a two-pen recorder. These are assembled in two packages, Figure 1, that are small and portable for maximum ease of use in field test work.

Figure 2 shows the block diagram. Mechanical gearing in the signal generator oscillates a baffle sinusoidally. The frequency range is from 0.0000362 to 0.739 cps, calibrated so that there is no need to calculate frequency. The test frequency can be changed while running. The mechanical-to-pneumatic signal converter changes the baffle motion into a pneumatic output pressure. It consists of standard Taylor components that provide a continuously adjustable output from 0.2 psi peak to peak to a maximum peak-to-peak amplitude of 12 psi (3 to 15 psi). Bias adjustment provides for changing the mean level of the sine wave to any level in the standard 3-to-15-psi range.

Standard Taylor Fulscope adjustable-sensitivity controllers, actuated by low-pressure receiving bellows, are used as amplifiers. Continuously variable and calibrated gains up to 12 can be obtained from each amplifier. Adjustments can be made while running. The position of the amplified wave on the chart record can be biased by means of the controller-amplifier set-point knob, permitting separation of the input and output traces on the recorder.

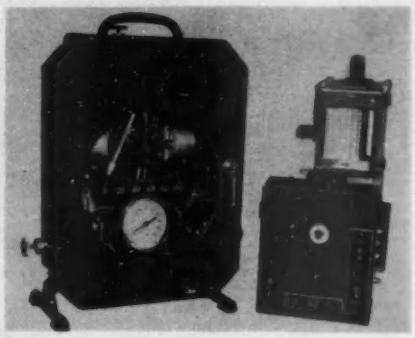


*FIG. 1. Two compact packages make up portable pneumatic sine-wave generator.*

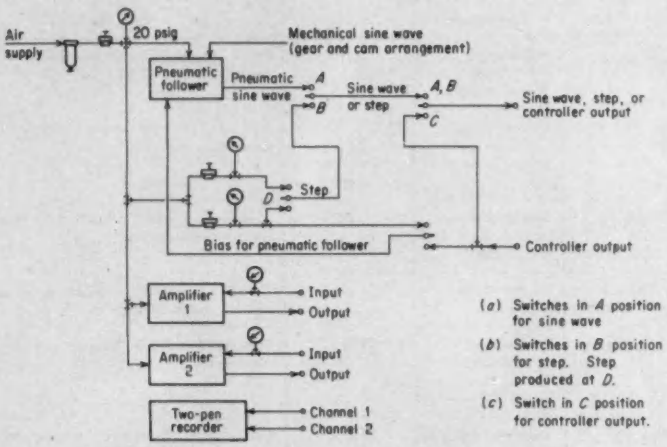



*FIG. 2. Selector switch permits choice of various outputs.*

The input signals are recorded on a 86J Taylor Transet two-pen recorder, with the chart driven from the output shaft of the gear train in the mechanical generator; this is the same shaft that drives the baffle-oscillating cam. In this way, chart speed is synchronized with test frequency, and a uniform wave length of 3 in. or 120 deg per in. results. This simplifies the interpretive procedure: phase difference between the input and output traces can be read directly, and always to the same scale, from the chart record.

Provision of switches and gages makes it easy to obtain step response curves, and to change back to normal control operation.

## 2. SERVO CORP. OF AMERICA SERIES 1100 SERVOSCOPES

The five models of the Servoscope, Figure 3, yield a variety of test inputs and provide versatile methods for evaluating control system performance. The frequency ranges covered are as follows: Model No. 1100A—0.1 to 20 cps, 1100B—0.15 to 30 cps, 1100C—0.3 to 60 cps, 1100D—0.001 to 20 cps, and 1100E—0.005 to 100 cps. Variable frequency is obtained by means of a speed-controlled ac motor. A calibrated 60-cps signal is compared to feedback-tachometer output. The frequency is accurate to better than plus or minus 2 percent of full meter scale in each range. Different gear trains increase the frequency range while maintaining accuracy of frequency setting constant.

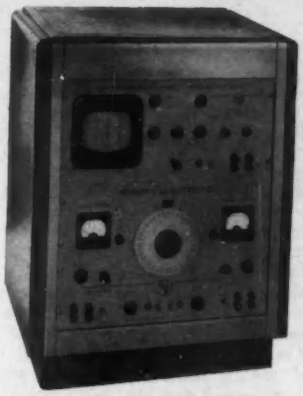


*FIG. 3. Typical Servoscope Model 1100, including integral scope for test evaluation.*

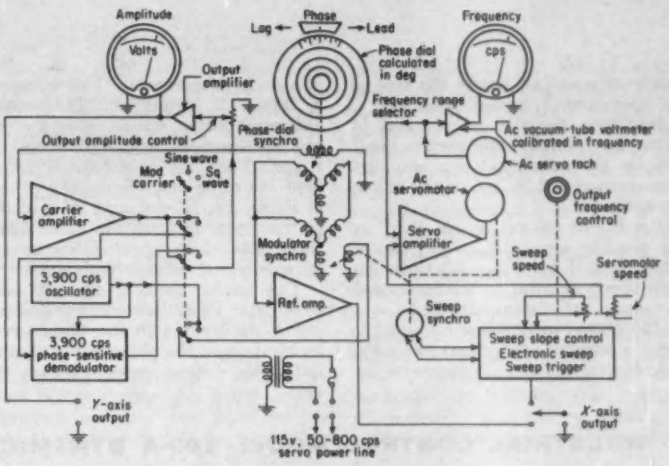



*FIG. 4. Block diagram of Servoscope.*

The Servoscopes provide four test signal outputs: 1) precision linear sawtooth sweep—0 to 150 volts peak, 2) sine wave—25 volts peak to peak, 3) square wave—25 volts peak to peak, and 4) modulated suppressed carrier—20 volts rms. The carrier frequency can range from 50 to 800 cps, with carrier output in-phase with the carrier applied as reference. These test signals are generated as follows:

A synchronizing switch on the output shaft of the drive mechanism triggers an electronic sawtooth signal generator, so that one sweep of the sawtooth corresponds to one revolution of the motor output shaft or to one cycle of the test frequency. Sawtooth output amplitude is kept constant by varying the input level inversely with frequency. Figure 4 shows a block diagram.

A combination of two synchros generates the sine-wave output. A modulator synchro, directly driven by the motor output shaft, is excited by a 3,900-cps signal source (internal to the Servoscope) when an unmodulated sine-wave output is required. The suppressed-carrier output of the modulator synchro is applied to a stationary phase-dial synchro, positioned by the phase-control knob on the front panel of the instrument. The phase angle of the modulation envelope and the rotor position of the phase-dial synchro vary together. The output of this synchro is demodulated and filtered to give a sine-wave output. Motor speed controls output frequency, and the phase of the output can be shifted with respect to the start of the linear sweep up to 360 deg lead or lag.

The square wave is generated by a bistable electronic circuit triggered by the sine-wave zero crossover. Since the triggering is done by a phase-shifted sine-wave, the origin of the square wave can be adjusted to exactly agree with the origin of the linear sweep. This is an important feature for calibration purposes, or when additional relays introduce their own delay.

The suppressed-carrier modulation signal is generated by the combination of modulator and phase-dial synchros; the carrier frequency signal to excite the synchros is provided from the control system under test.

Note that there is another output available from the reference amplifier. When an unmodulated sine-wave output is being generated, the reference amplifier output is a 3,900-cps suppressed-carrier signal whose modulation envelope is in phase with the linear sweep. When the suppressed-carrier output is being generated, the reference output has the same frequency and its modulation envelope is also in phase with the sweep.

A high-quality dc scope or a scope designed for the Servoscope (see top of Figure 3) is required to perform frequency- or transient-response tests. The integral scope has characteristics of phase equality, trace sharpness, stability, etc., that make it especially suitable for such measurements. At very low frequencies (below 0.5 cps) other recording and evaluation means must be used.

Transient-response testing can be accomplished by using the square-wave output as a forcing function and observing control system output on the oscilloscope with the linear sweep driving the *x* axis. Note that this permits evaluation of delays in control system response. The square-wave output is not a suppressed-carrier signal. The latter can be obtained (as with any square-wave signal generator) by driving a relay whose contacts introduce an ac step input signal to the control system. The linear sawtooth and sine-wave outputs can be used to determine velocity constant and fre-

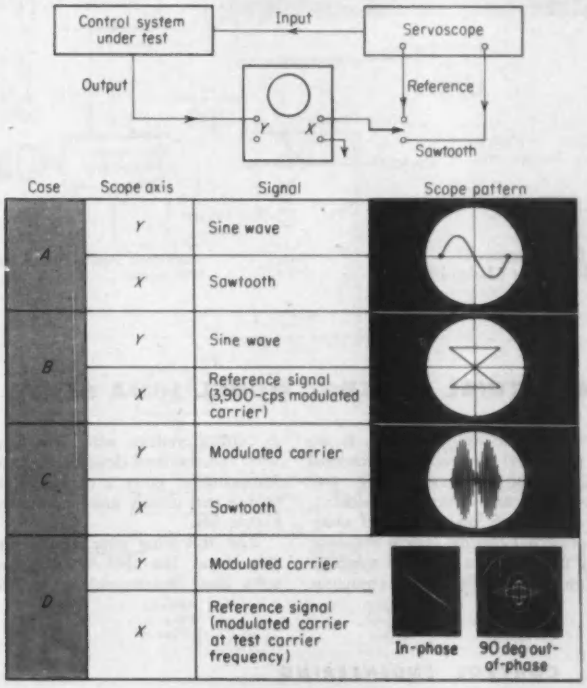



*FIG. 5. Phase measurement with a Servoscope.*

quency response on almost any type of electromechanical control system.

Amplitude response is measured by noting the control system output amplitude on the calibrated y-axis amplifier. Phase is measured by one of the following methods:

If it is a dc control system, there are two possible approaches. First, control system output is displayed against the linear sweep provided by the Servoscope. The phase dial is manipulated (by varying the control input phase compared to sweep initiation) to adjust the scope pattern until the output sine wave begins as the sweep begins. This technique is shown in Figure 5A. The second, and more precise, way is to use the output of the reference amplifier on the *x* axis. Then the phase dial is moved until the scope shows the closed pattern of Figure 5B. The straight sides of this pattern open up when the phase differs from zero. Zero phase difference can be rapidly and accurately obtained.

Two similar methods are used with ac systems. First, the control system output is displayed with the linear sweep on the *x* axis. The phase dial is adjusted until the output pattern shows one cycle starting at the same time as the sweep. This gives the scope presentation of Figure 5C. The second way is, again, to display control system output vs. reference amplifier output. When these two suppressed carrier signals are in phase, the pattern on the scope degenerates to a straight line.

In all cases the phase-dial reading is the phase shift of the point of the control system under study (output, error channel, etc.) with respect to the input. Phase shift in the Servoscope can be calibrated out by phase measurement between its output and the test signal.

## 3. INDUSTRIAL CONTROL MODEL 100-A DYNAMIC ANALYZER

The Model 100-A Dynamic Analyzer, Figure 6, provides test signals that are adequate for both frequency response and transient response testing. It is a simple, compact device whose portability makes it attractive. Modifications for special test procedures are easily made.

Test signals include the following: 1) suppressed-carrier modulated signal with a modulation frequency of 0.5 to 50 cps (lower frequencies are available on nonstandard units); carrier frequency—internal, 60 cps; external, 40 to 1,000 cps; output amplitude—1 volt rms; 2) square wave with a repetition frequency of 0.5 to 15 cps; carrier frequency output—60 cps at 1 volt rms or as supplied from external source; 3) high-power spdt switch capable of handling several hundred watts ac or dc at test frequency; 4) sweep voltage (synchronized with sine and square waves) for direct drive of a cathode-ray oscillograph with variable amplitude and position; amplitude—230 volts peak to peak. A dc sine wave can be obtained with a demodulator or by adding a sine-cosine potentiometer to the motor shaft (available on nonstandard units).

These signals are generated as shown in Figure 7. A thyratron-controlled permanent magnet motor yields good regulation over a speed range of greater than 100:1. Frequency is indicated by a voltage measurement derived from a network in the cathode circuit of the thyratron. The suppressed-carrier signal is generated by a rotating synchro, with the modulation frequency equal to the speed of rotation. The rotating synchro feeds the phase-adjusting (stationary) synchro. Modulation phase can be adjusted to 360 deg lead or lag by positioning the rotor of the phase synchro. The motor output shaft also drives a cam and a linear potentiometer. The cam actuates a switch to yield step input voltages. Contacts are provided to switch high-power-level signals. The linear potentiometer generates the sawtooth reference signal.

The methods for measuring response of a control system with this analyzer are almost identical to those used with the Servoscope (see Figure 5).

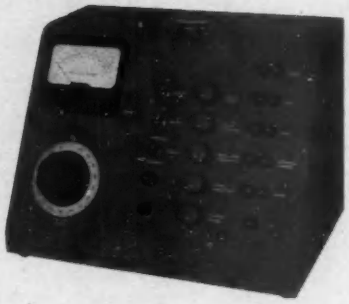


*FIG. 6. Compactness and ease of modification to handle special test requirements make this unit particularly attractive.*

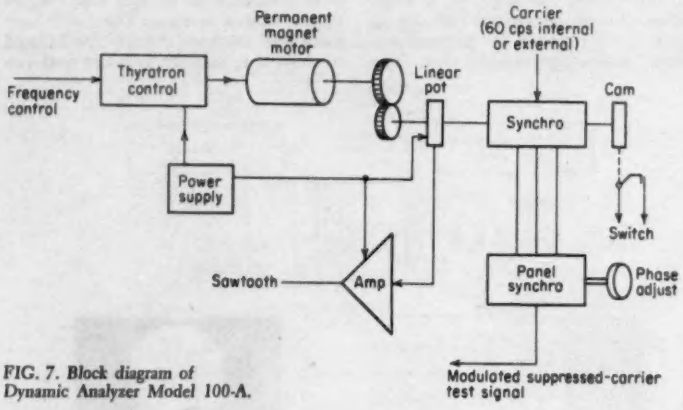



*FIG. 7. Block diagram of Dynamic Analyzer Model 100-A.*

## 4. INDUSTRIAL CONTROL MODEL 101-A SERVO TESTER

This unique device, Figure 8, is intended primarily for evaluating control system transient response during production testing and system adjustment. Operation depends on the visual comparison of actual control system response to a step input with a standard response plotted on a mask. Figure 9A compares a control system with low loop gain with the standard desired response. Gain readjustment gives a control system response that closely matches the standard, Figure 9B.

The following step inputs are available from the 101-A: amplitude—10 volts rms (maximum) ac or 40 volts

*FIG. 8. Servo Tester designed for production line use.*

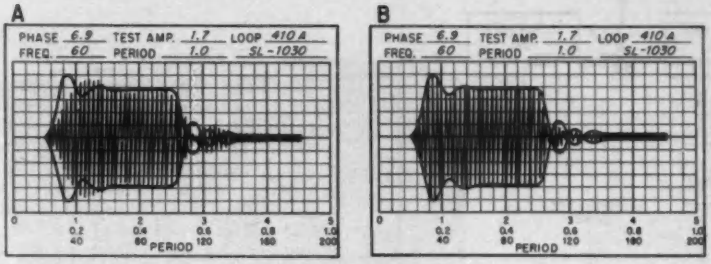



*FIG. 9. A—Actual response shows that gain is too low. B—Gain readjustment makes system response coincide with standard response on mask.*

(maximum) dc; carrier frequency—60 or 400 cps; carrier phase—plus 45 to minus 80 deg. Step input periods of 0.2, 1, and 5 sec are available. (Test signal characteristics can be modified in nonstandard units.)

System response is visually presented on a 3-in. long-persistence scope. A holder keeps the transparent mask with its standard response in position in front of the scope. The sweep is synchronized with the test input to the control system. Intensity, focus, x and y gains, and position can all be adjusted. Production testing is facilitated by using a prepared cable to interconnect the control system and the tester.

The test signal is injected into the error channel of the control system, moving the system away from its former output by the amplitude of the step and permitting it to return to its original position when the input returns to zero. This test method permits simultaneous evaluation of system overshoot, rise time, natural frequency, and damping, as well as the static error level. The latter is observed by noting the variation in output when the step input is removed.

A repetitive input gives a continuous scope presentation of system response, permitting the operator to adjust the control system on an almost continuous basis. Photographic records are easily obtained for studying the long-time characteristics of a control system.

It is apparent that the Servo Tester is applicable to field testing as well as production testing of control systems. A 60-cps, 110-volt line and a compatible plug on the control system are the only auxiliaries required by the device.

## 5. MINNEAPOLIS-HONEYWELL SERVO ANALYZER

The Servo Analyzer developed by the Industrial Products Group of Minneapolis-Honeywell Regulator Co. is a complete apparatus for measuring and recording control system frequency response data. Particular emphasis is placed on the very low frequency region and on providing a sinusoidal air pressure signal compatible with pneumatic process control systems. The analyzer, Figure 10, consists of a signal generator, portable potentiometer, control box, and function plotter.

Signal-generator output frequency is determined by a two-phase 60-cps servomotor, speed-controlled by a tachometer, calibrated input, and servoamplifier. The motor output shaft drives test signal generators, and reference and timing signal generators; this is shown in Figure 11. The main drive shaft, rotating at signal frequency, actuates all of the sinusoidal generating components.

Electrical sinusoidal signals are obtained from two linear slidewires driven by scotch yokes. A calibrated differential separates the two yokes, providing a means of setting the relative phase of the two outputs. The main shaft also drives a sampling contactor, which is used for performance evaluation (as discussed below). The contactor unit consists of four normally-closed contacts that are periodically opened by a set of single-lobe cams driven at twice the test speed. The signal generator covers a range of from 1 cycle per hour to 10 cps.

The signal generator also yields a pneumatic sinusoidal test signal. The main shaft drives a wobble plate, which in turn transmits a sine-wave displacement through an adjustable linkage to a pneumatic generator. Pressure feedback establishes a sinusoidally-varying air pressure that follows the position input. The

*FIG. 10. Servo Analyzer: signal generator, lower right; portable potentiometer, upper right; control box, lower left; and function plotter, upper left.*

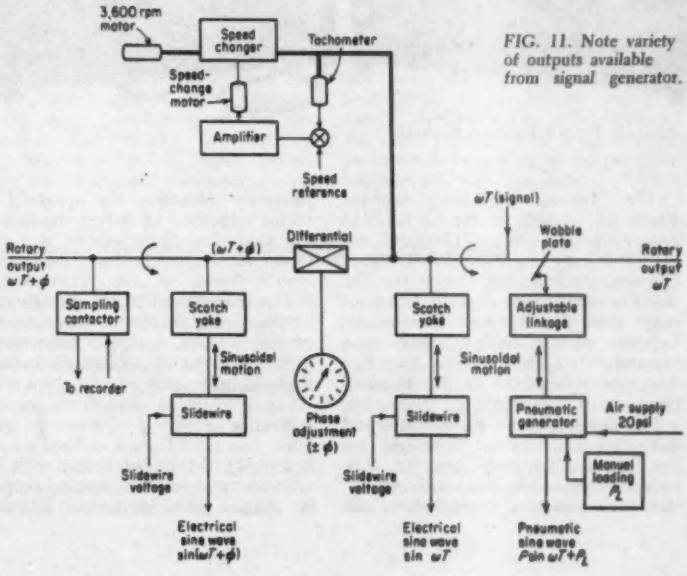



*FIG. 11. Note variety of outputs available from signal generator.*

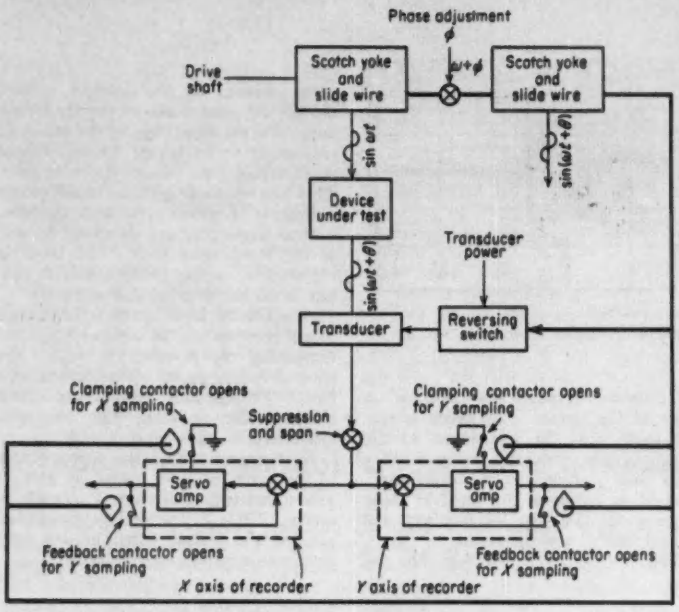



*FIG. 12. Sampling method of measuring frequency response.*

pneumatic test signal has the following characteristics: amplitude range—0.05 to 7.5 psi; level—1 to 19 psi; supply—20 psi; hysteresis—1 percent of full scale; linearity—1 percent of full scale; frequency response—flat to 300 cpm at 9 plus or minus 0.6 psi dead ended, flat to 80 cpm with 100 in.$^3$ load volume.

The portable potentiometer provides the calibrated input to set the test frequency, and the control box contains all of the controls for adjusting recording on the function plotter. The latter is a a two-axis (x,y) self-balancing recorder.

The Servo Analyzer uses a sampling method for evaluating control system output. Figure 12 shows the overall system. The sampling system gives the x and y (amplitude and phase) components of control system output. To measure the x and y components, the output voltage is sampled at the 0-deg, 90-deg, 180-deg, and 270-deg points of the input sine wave. The 0- and 180-deg samples are used to position the x axis of the recorder, the 90- and 270-deg points to position the y axis. To obtain signals of the same sign for both test points, transducer excitation (on the control system output—not the feedback sensor) is reversed every half-cycle. The recording circuits only respond to their input during the sampling period. Thus, as the input frequency is altered, the recorder moves from the previous position of output amplitude and phase to a new position corresponding to the new amplitude and phase.

For high-frequency testing, the second slidewire can be excited and used as the x-axis reference for a Lissajous pattern. Phase adjustment can then be used to obtain a closed pattern on the scope and thus an accurate reading on the phase dial. The control system output transducers (slidewire or strain gage) are excited with 60 cps, since the recorders used with this system are 60-cps suppressed-carrier devices.

## 6. SOLARTRON MARK II TRANSFER FUNCTION ANALYZER

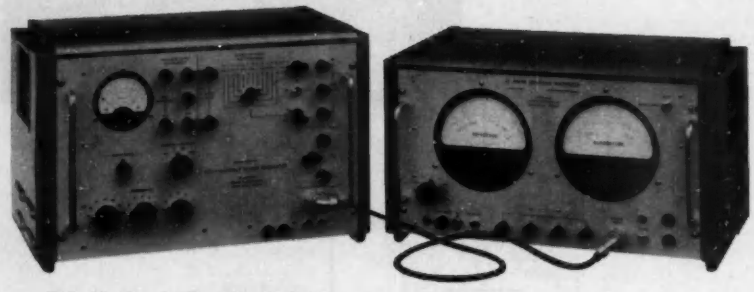


*FIG. 13. Transfer Function Analyzer.*

The Transfer Function Analyzer, Figure 13, consists of the O. S. 103A Low Frequency Decade Oscillator and the VP 253.2A Low Frequency Resolved Components Indicator. Since the Decade Oscillator covers a greater frequency range than the Resolved Components Indicator, it was treated under signal generators (see Part I, Item 5). This discussion is confined to the Resolved Components Indicator.

The device displays the in-phase and quadrature components of control system response on two separate 6-in. meters. The meters are zero-centered, and their direction of deflection immediately identifies the quadrant of vector response. Operation depends on the square-law characteristics of a thermocouple. Figure 14 shows the thermocouple bridge circuit. Thermocouple emf is proportional to the average value of the integral of the instantaneous current squared, and the indication is proportional to the difference between thermocouple emfs, or

$$\text{Indication} = \frac{K}{t}\left[\int_0^t i_2^2 dt - \int_0^t i_1^2 dt\right]$$

Energizing the bridge circuit with the reference and control system outputs, as shown, gives a meter indication that is proportional to the following:

$$\frac{K}{t}\int_0^t V_r V_s \, dt$$

where $V_r$ = reference voltage
$V_s$ = signal voltage

When $V_r$ is of the form $E \sin \omega t$, the above integral is zero for all components of the signal voltage except the in-phase component $V_s = A \sin \omega t$. Higher harmonics, noise frequencies, and the quadrature component integrate to zero. This is true to the extent that the thermocouple follows the square law.

The second meter, being excited by a reference voltage that is in quadrature with the signal to the control system, has an output equal to the quadrature component of control system response. Amplitude and phase can be easily calculated when the in-phase and quadrature components of system response are known.

The Resolved Components Indicator has a useful frequency coverage of 0.5 cps to 1 kc; operation below 0.5 cps is possible by taking mean meter readings. Noise and harmonic rejection is better than 40 db down. Full-scale meter indication is achieved for as little as 50 mv input, and up to 150 volts of a control system output can be measured.

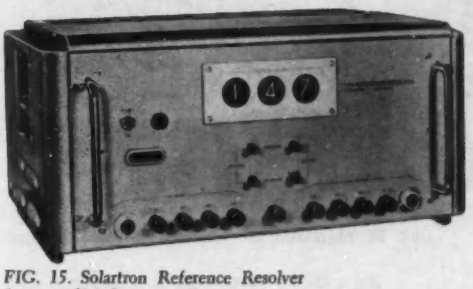


*FIG. 15. Solartron Reference Resolver features digital presentation.*

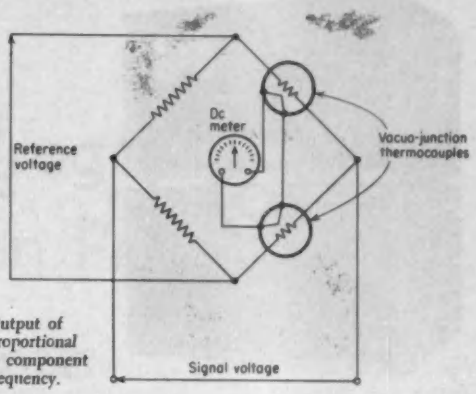



*FIG. 14. Output of bridge is proportional to in-phase component at signal frequency.*

Input impedance is 1 megohm unbalanced and 2 megohms balanced. A reference voltage of 10 volts rms at 0 deg, 90 deg, 180 deg, and 270 deg is required (normally provided by an O.S. 103A oscillator). Accuracy of indication is plus or minus 3 percent of full scale on all ranges.

Very recently a Reference Resolver JX 746, Figure 15, that permits direct digital reading of phase angle and amplitude, was added to the Transfer Function Analyzer. When interconnected with the Resolved Components Indicator, the Reference Resolver adds a calibrated phase shift to the four reference phases. By adjusting the phase shift until the quadrature component meter reads zero, the net phase shift can be read on the Reference Resolver, and the amplitude ratio on the in-phase meter. Thus the Reference Resolver converts the Transfer Function Analyzer from a quadrature/in-phase device into an amplitude/phase-measuring system. The Reference Resolver sells for $945.

The self-contained noise rejection characteristics of this instrument make it useful for low-amplitude tests and for tests performed under noisy conditions.

## 7. SOLARTRON JX 563A SERVO TEST SET

The Servo Test Set, Figure 16, based on the principles of the Transfer Function Analyzer, is intended for use in production tests. It contains a low-frequency amplitude-stabilized oscillator, which operates like the O.S. 103A described under Item 5 in Part I of this series. The standard unit provides test signals with these characteristics: frequency—0.5 to 500 cps; amplitude to 20 volts rms at 5 ma rms; dc output—less than 2 percent of peak-to-peak output; harmonics—less than 2 percent; accuracy—plus or minus 2 percent with 1 percent resistors.

Four different test signal frequencies can be set into the JX 563A by inserting the proper resistors ($R = 5/f$) in the programming panel (see figure). At each of these four test points, the test input amplitude is adjusted by means of a potentiometer (located behind the programming panel) and calibrated against a meter on the front of the instrument. In addition, at each of the four points, the expected output amplitude from the control system (0- and 90-deg components set separately) are set by referring to the meter. The unit is calibrated to handle return signals from the control system of from 30 mv to 100 volts rms. Finally, the desired tolerance limits on the 0- and 90-deg components are set.

Note that all of these adjustments are made by means of devices located behind the programming panel. Thus the operator conducts a go/no-go test, or makes his adjustments to meet the limits, but he does not alter the desired results once they have been established by the engineer in charge.

A simple switch takes the test from one point to the next until the four points have been completed. The four meters on the top show test signal amplitude, return signal amplitude, tolerance on the 0-deg component, and tolerance on the 90-deg component. The metering circuits that measure the return signal 0- and 90-deg components operate like those described for the Resolved Components Indicator, so that the measurement largely rejects noise, harmonics, and quadrature.

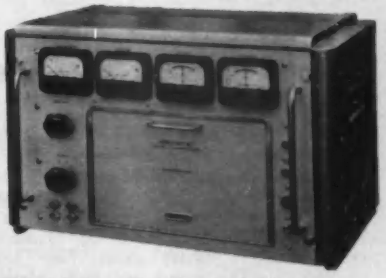


*FIG. 16. Servo Test Set stands alone in making production frequency response testing practical as well as accurate.*

Because it combines ease of setup, accuracy of control system output measurement, rapidity of operation, and completeness of function within one instrument, the JX 563A is an invaluable aid in the production testing of control systems. The availability of four test points makes it possible to perform a relatively complete frequency response test with one setup.

## 8. SHORT BROTHERS & HARLAND CONTROL SYSTEM ANALYZER

The Control System Analyzer, Figure 17, recently announced by Short Brothers, combines a low-frequency decade oscillator with a unique method of determining the real and imaginary components of the returned signal.

The low-frequency oscillator generates sinusoidal signals from 0.01 to 109.9 cps. Settings are made by decade switches and the complete frequency band is covered in four ranges. The accuracy of the frequency setting is plus or minus 2 percent, and amplitude is controlled to plus or minus 1 percent. Maximum output is 20 volts peak at 15 milliamps, and the output amplitude is continuously adjustable from 0 to 20 volts by means of a 10-turn pot. Harmonics are less than 0.5 percent, while the dc output is less than 0.005 percent of the peak sinusoidal output.

When the oscillator is turned on, output starts from zero and immediately assumes the correct steady-state amplitude—there is no transient. When switched off the output decays exponentially to zero. Ramp and step voltage outputs are also available. The ramp can be varied from 0.1 to 100 volts per sec, while the step has a maximum output of 20 volts at 5 milliamps.

The Control System Analyzer consists of plug-in type continuously-drift-

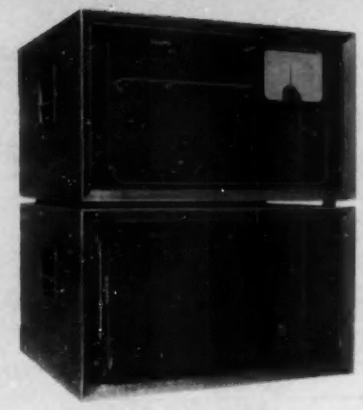


*FIG. 17. Control System Analyzer and power supply.*

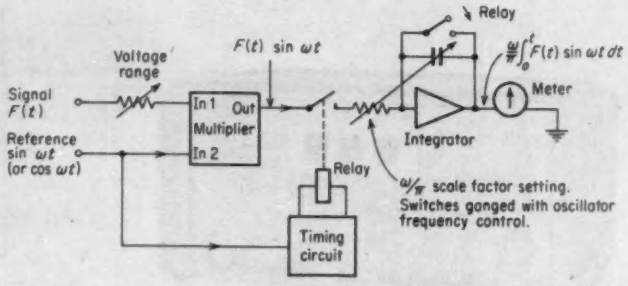



*FIG. 18. Phase-sensitive voltmeter section of analyzer.*

corrected dc amplifiers. The phase-sensitive voltmeter section of the analyzer, Figure 18, evaluates the Fourier expression for the in-phase and quadrature components of the fundamental in the waveform under test. These are

In-phase component =

$$\omega/\pi \int_0^T \sin \omega t\, F(t)\, dt$$

and quadrature component =

$$\omega/\pi \int_0^T \cos \omega t\, F(t)\, dt$$

where $F(t)$ = output of system under test
$\sin \omega t$ = signal into system under test
$T$ = period of one cycle of test frequency

Integration over one cycle is achieved by operating a relay, and the result of this integration can be read from the meter. A memory circuit performs a hold action on this value, so that at low test frequencies the meter reading is steady. This method of evaluating the two components of system output gives better than 40 db rejection of all higher harmonics of the test signal frequency in the control system response. Dc in the control system response is completely rejected.

Note that the integrator time constant is changed simultaneously with oscillator frequency. This provides the meter with the proper scale factor by taking into account the $\omega/\pi$ term of the above equations. Full-scale readings of up to 150 volts and as low as 50 millivolts are provided in eight different ranges in this analyzer.

## 9. BOONSHAFT & FUCHS FEEDBACK CONTROL SYSTEM ANALYZER

The Feedback Control System Analyzer being manufactured by Boonshaft & Fuchs under license from Shell Development operates on a principle that was described in detail by Percy Cowley in "The Application of an Analog Computer to the Measurement of Process Dynamics", ASME paper No. 56-IRD-20. The instrument itself comes in two cabinets, the first containing a low-frequency variable-phase oscillator, and the other the return-signal analyzing equipment.

A block diagram of the entire system is shown in Figure 19. The low-frequency oscillator covers a frequency range from 0.05 to 200 cps, and is based on a conventional operational amplifier solution of $d^2y/dt^2 = -y$. A unique circuit is used to combine the sine and cosine signals (made available for the return-signal analyzing equipment) into a continuously variable phase output with an accuracy of plus or minus 1 deg over the 0-to-180-deg range. This variable-phase output is then used to drive the system under test, with a maximum output of plus or minus 50 volts into 2,000 ohms. A 10-turn pot provides a continuously adjustable output with two ranges of 0.5 and 50 volts. The dc output is less than 0.05 percent of signal level.

Because of the variable output, the low-frequency oscillator section can be used for frequency response measurements in conjunction with a scope, as described under Items 2 and 3 above. (The reference phase is available for the scope x axis.) Where noise is not a problem, or where direct observation is desirable, this is a useful feature.

Output amplitude is stabilized to plus or minus 1 percent, and the oscillator yields no transient when turned on.

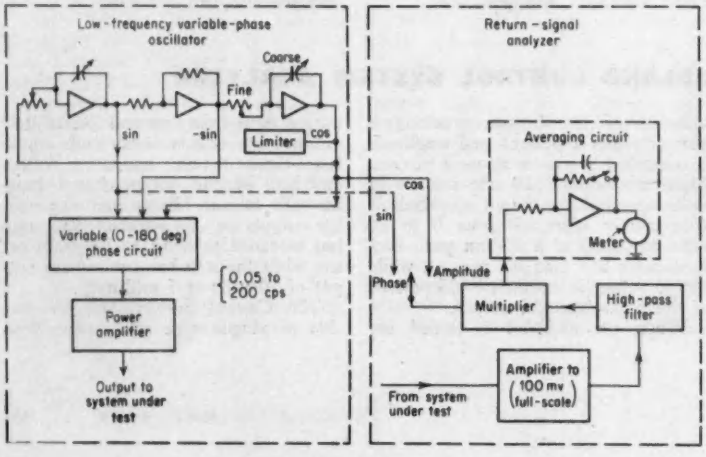
The signal analyzer section consists of a return-signal amplifier, a high-pass filter, a multiplier, and an averaging circuit. The amplifier provides adequate stabilized gain to give a reading sensitivity of 100 millivolts. The high-pass filter, with its break frequency set at the test frequency, rejects noise at frequencies below its break point. This is important for low-frequency testing when the system is being disturbed.

The multiplier and averaging circuits are initially used to multiply the returned signal by the sine reference signal and to average the result of this operation. When the average is zero, the phase dial reads the phase shift through the item under test. Using the cosine input to the multiplier, the meter in the averaging circuit output indicates amplitude. If this reading is negative, the phase shift is read at 180 to 360 deg.

Provision is also made for switching out the resistance of the averaging circuit and for using the operational amplifier as an integrator. In this case, employing the alternate quadrature components method described in Cowley's paper permits particularly noisy systems to be measured accurately.

The low-frequency variable-phase oscillator can be purchased separately for $2,500, and the return-signal analyzer for $1,500.

*FIG. 19. Simplified diagram of complete system.*



# Transistorized Programmer Runs 35,000-Ton Press

**LEO ROBBINS and ANTHONY L. LICCARDI**
**Loewy-Hydropress Div., Baldwin-Lima-Hamilton Corp.**

**A transistorized digitally-programmed speed-control system is successfully turning out zero-draft forgings on one of the largest presses in the world. The system changes pressing speed four times in a forging cycle at press platen positions accurate to 1/16 in. in a 6-ft stroke—on a machine heavy enough to produce 35,000 tons of force.**

Automatic controls have generally been considered unnecessary for forging presses because the quality of conventional forgings is not much affected by speed variations during the forging cycle. Speed variations are small in any case, because of the tremendous moving masses in large forging presses and the short forging cycle, so that manual control is sufficient.

The recent introduction of zero-draft forgings, however, has made it advantageous to replace the manual speed control with an automatic speed program. Zero-draft forgings are shapes produced by forging in closed dies, with exactly parallel walls, and without the usual draft angles, see Figure 1. Conventional forgings, just like castings, are made with large draft angles. The material that enters the wide opening of the die cavity is initially deformed, and the deformation continues as the metal flows into the narrow end of the cavity. The continuous deformation requires large forces and, hence, presses are limited in the size of forgings that can be made. In zero-draft forgings the material is deformed only as it enters the die cavity. For the remainder of the forging cycle, the material is not reworked until it hits the bottom of the die-cavity, where a slight additional deformation takes place.

Zero-draft forgings are especially advantageous for aircraft because they make it possible to achieve a better weight-strength ratio than conventional forgings. With conventional aircraft forgings, the ribs must be machined, wasting expensive alloys, consuming time, and decreasing the structural strength of the rib by cutting across the flow lines, Figure 1C. Zero-draft forgings require little or no machining; their flow lines are essentially parallel, resulting in higher strength ribs, Figure 1D.

To make zero-draft forgings, however, the speed of extrusion of the material into the die cavity must be closely controlled. An excessively high forging speed may result in tears and uneven filling of the die cavities; too slow a speed may cause uneven cooling of material and interrupt the forging cycle. The optimum speed of forging, which may vary during the forging cycle, will produce high quality forgings at a minimum expense.

An automatic program speed control was designed

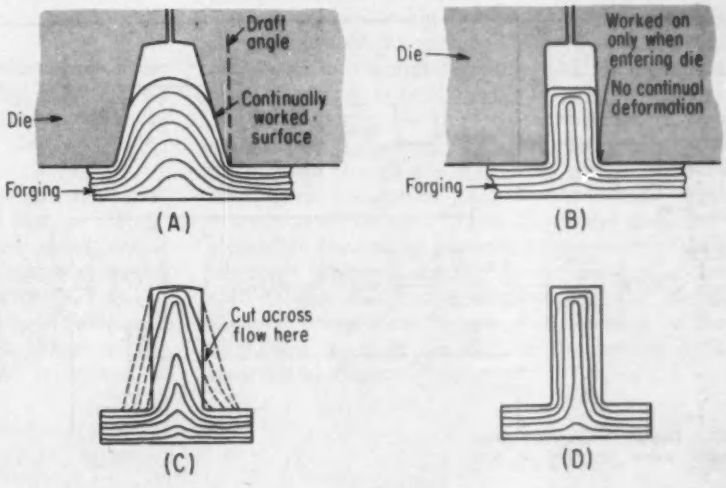



*FIG. 1. A—Conventional forging, showing material flow lines. B—Zero-draft forging. C—Conventional forging, showing how necessary machining cuts across flow lines to weaken part. D—Zero-draft forging needs little or no machining; flow lines are not cut.*

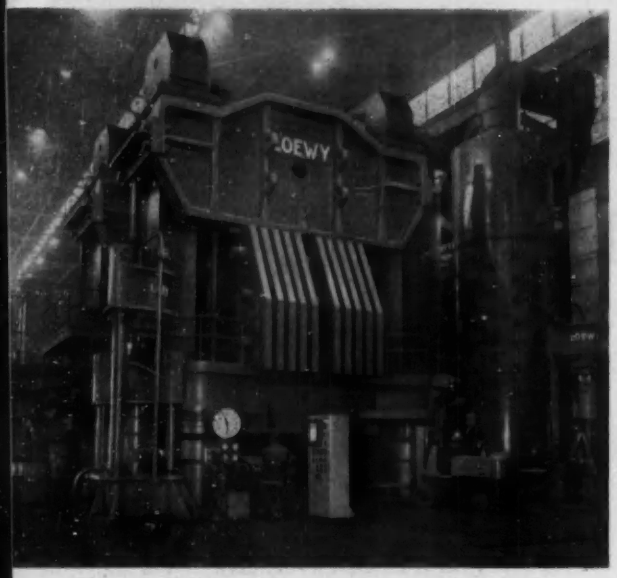



*FIG. 2. 35,000-ton forging press showing automatic speed-control cabinet in foreground.*

and manufactured under a United States Air Force contract, and installed on the 35,000-ton Loewy press at the Wyman-Gordon plant, in North Grafton, Mass., Figure 2. This is the only press of this type with automatic program speed control.

## Speed-control system

To approximate the optimum forging speeds, the automatic control system for a press must be programmed to change speeds at preselected positions of the press stroke. Thus, position of the press platen is converted to rotation of the shaft of an analog-to-digital encoder, Figure 3. A tachometer-generator signal is proportional to press speed.

The outputs of the encoder are dc signals in reflected binary code which, after passing through preset position-selection code switches, are fed into a transistor switching matrix. When the signals from the encoder coincide with the setting of the code switches (indicating that a speed change has to be made), the transistor switching matrix actuates a control relay. The relay, in turn, connects the voltage of a speed-setting potentiometer to one input of the difference voltage amplifier.

The speed-setting potentiometers are preset to give a voltage which should be identical to the voltage generated by the tachometer when the press is moving at the proper speed. The difference between the potentiometer voltage and the tachometer voltage is amplified to drive an electrohydraulic servovalve that controls an hydraulic actuator. This actuator shifts the spindle of the throttle valve on the press. Thus, the water flow to the large press cylinders is controlled by the difference between the speed-set and tachometer signals.

Note that the tachometer voltage is recorded at all times for later analysis. The recorded voltage is modified by nonlinear filters to make the indication logarithmic and thus facilitate reading and interpretation of the records.

## Automatic programming

The transistor switching matrix is shown in Figure 4. The matrix consists essentially of two banks of p-n-p transistors and one p-n-p power transistor for actuating the control relay. The conducting segments and brushes of the encoder are represented schematically by a series of on-off switches. The coded binary switches are represented schematically by a series of single-pole, double-throw switches.

As the press moves, the encoder continuously transmits its position, represented by the closing of switches according to a reflected binary code. A conducting segment represents a binary one (1) and a nonconducting segment a zero (0). Figure 4 shows that when a coding switch is in position one (1), its transistor in the second bank will conduct only when its encoder contact is open. If, however, a coding switch is in position zero (0), the action will be reversed by the transistor in the first bank, and the transistor in the second will conduct only when its encoder contact is closed.

The power transistor will conduct and energize

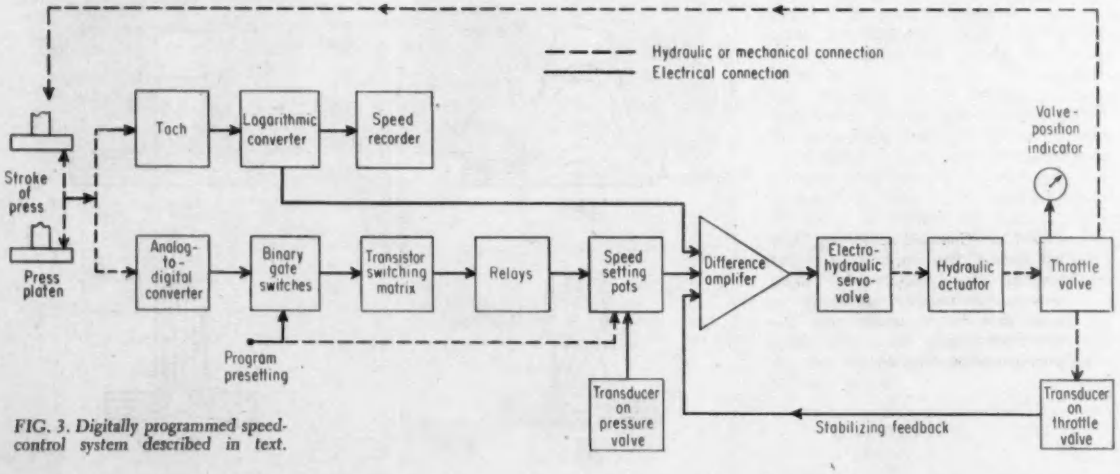



*FIG. 3. Digitally programmed speed-control system described in text.*

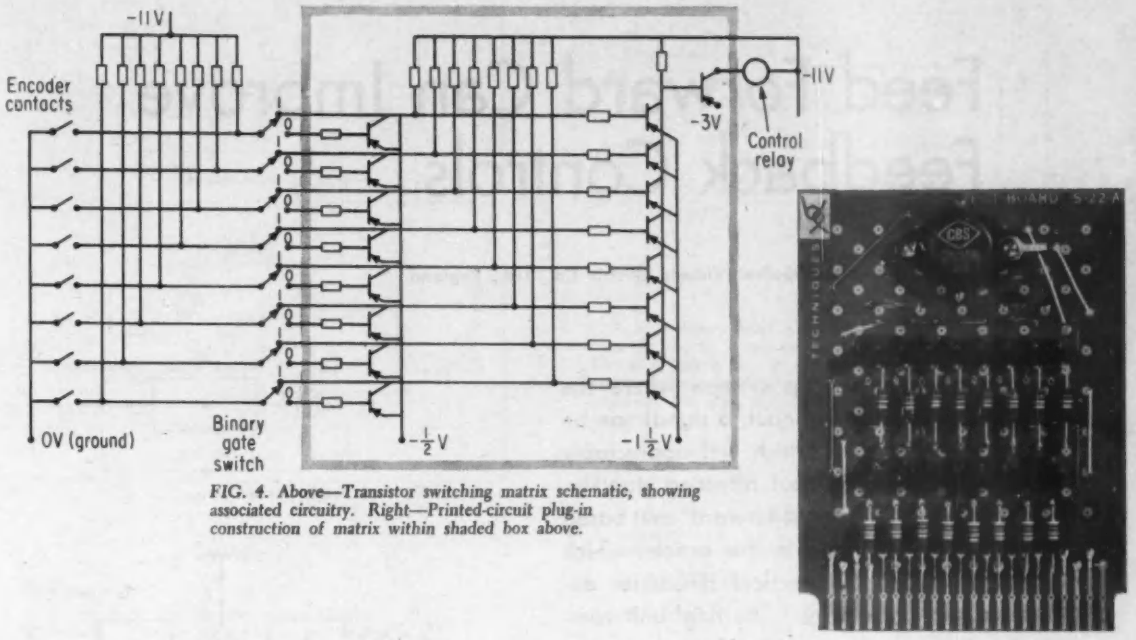



*FIG. 4. Above—Transistor switching matrix schematic, showing associated circuitry. Right—Printed-circuit plug-in construction of matrix within shaded box above.*

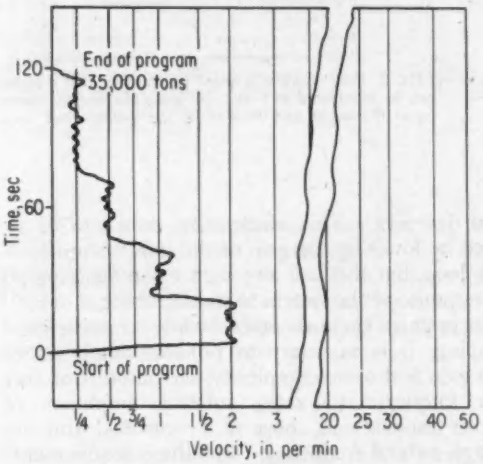



*FIG. 5. Recording of press velocity vs. time for a typical forging cycle.*

the control relay only when all second-bank transistors are nonconducting at the same time; that is, when coincidence occurs between the coded number set by the binary gate switch and the coded position signal from the encoder.

There are four such gate switches and four transistor matrices in the press-control system. These serve to select four different preset speed potentiometers as the press reaches four preset positions. Actually, adjustable timers are interposed between each of the selection relays and the speed-set potentiometers, so that an abrupt speed change is not called for. Instead, the press speed is allowed to coast to a lower speed for a few seconds (by closing the throttle valve) before the new speed-set voltage is applied to the difference amplifier.

This coasting and the control behavior at the four preset speeds can be seen on the speed recording in Figure 5 for a typical programmed run. The reason for the logarithmic filter is also seen in the good detail recorded at very low speeds. The system can control the press at speeds up to 50 in. per min as indicated by the chart calibration.

To protect the dies, a pressure limit control automatically limits the pressing force. The limitation must occur within the range specified for any particular die to avoid overstressing the die. The pressing force limit control overrides the automatic or manual speed-control system if the preset maximum pressure is approached, and temporarily resets the speed control to a lower value to coordinate it with the preset pressing force. An indication of the approach to the preset limit is therefore required.

A special indicating pressure relief valve senses the approach of the pressure in the hydraulic cylinders to the preset maximum allowable pressure, and when the pressure in the cylinders reaches approximately 90 percent of the maximum allowable, the valve causes the voltage across the preset speed pots to diminish at such a rate that the voltage becomes zero when the preset pressure is reached. This action causes the press to slow down and eventually stop when the critical pressure is approached before the relief valve will open. The same action is also used to stop the press upon closure of the dies at the end of each cycle (note the reaching of the 35,000-ton limit at the end of the forging cycle recorded in Figure 5).

# Feed Forward Can Improve Feedback Controls

R. L. DUTHIE, Metropolitan-Vickers Electric Co., Ltd., England

**THE GIST:** In closed-loop systems where the error is a function of the input, a signal can be derived from the input which will appreciably reduce system error without affecting stability. The development of a "feed-forward" unit based on this fact is described in this article, which includes discussion of practical difficulties encountered along the way. The final unit compensates zero-velocity-error position servos, but the techniques are applicable wherever system error is a function of the input signal. Where it is not, however, feed forward can have no effect. Load disturbance is an instance.

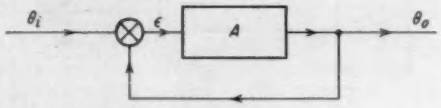



FIG. 1. A simple position servo.

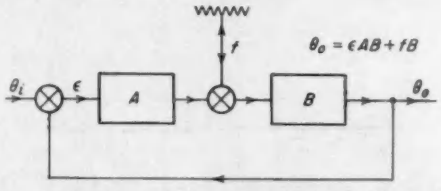



FIG. 2. Feed forward is based on the fact that a signal can be introduced at f that will make the output exactly equal the input and thus make the system error zero.

The accuracy of any closed-loop or negative-feedback system is a function of the gain within the loop; i.e., in a position control (Figure 1):

$$\frac{\theta_o}{\theta_i} = \frac{A}{1+A}$$

where A is the gain within the loop and feedback factor is unity. This equation shows that in straightforward position servos the output and input positions cannot be equal, and there must be an error:

$$\epsilon = \theta_i - \theta_o$$

In such a system the error is essential, since it must control, when amplified, the power to maintain the desired motion of the load. It would appear that by making A sufficiently large, the value of $\epsilon$ could be reduced to any desired (finite) smallness, but in fact the maximum usable value of A is limited by servo instability.

The subject of stabilizing methods for closed-loop systems has been widely dealt with; and it is not proposed to air the matter here, beyond noting that it has been found satisfactory to stabilize position servos by a combination of phase-advance and lagging acceleration feedback techniques. Thus, it is not uncommon to achieve usable values of A such that maximum errors are 1 min of arc or less in constant velocity conditions, and in the order of 0.3 to 0.5 min of arc per deg per sec$^2$ during acceleration, with good damping. This acceleration error can be reduced by lowering the gain of the stabilization feedback loop, but this will also reduce the damping on the response of the system to sudden changes of $\theta_i$.

To improve these accuracies while retaining good damping, it is necessary to produce amplifiers of high gain and some complexity, servomotors of very high torque/inertia ratio, rotating amplifiers of quicker response and, above all, a controlled structure of high natural frequency. But these requirements cause difficulties and there is a clear need for some better method of improving servo accuracy.

Consider a servo with loop gain A (Figure 2), to which an input signal can be introduced from a manually controlled source. This signal will give some control of the output angle, $\theta_o$, but clearly cannot affect the stability of the loop, since it originates from outside the loop. If this signal can be given such form that its effect on $\theta_o$, while the servo is following $\theta_i$, is to reduce the value of $\epsilon$, then the dynamic accuracy of the system has been improved without an increase of loop gain and its attendant servo stability problems. This is the basis of "feed forward", as this technique is known.

## Feed forward

Before a suitable feed forward can be decided upon, it is necessary to know the nature of the system

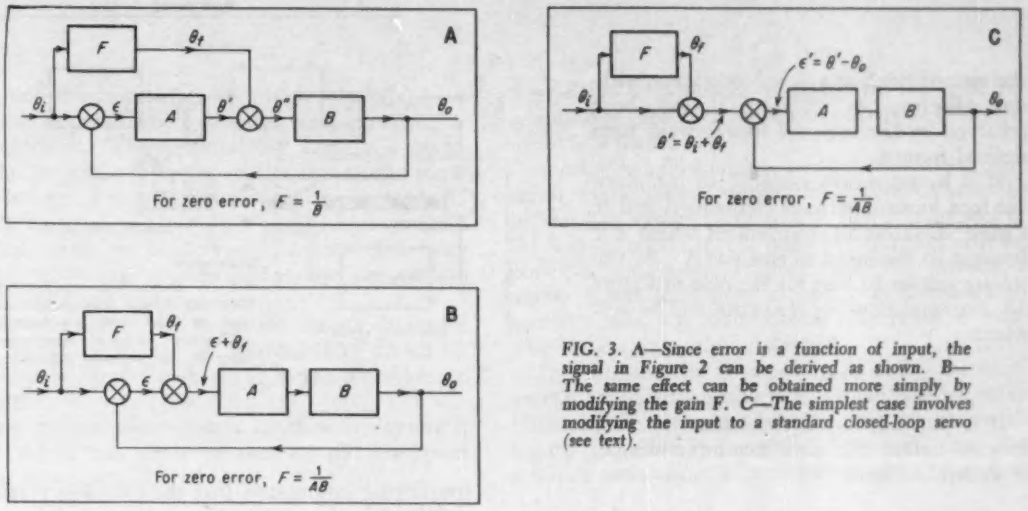



*FIG. 3. A—Since error is a function of input, the signal in Figure 2 can be derived as shown. B—The same effect can be obtained more simply by modifying the gain F. C—The simplest case involves modifying the input to a standard closed-loop servo (see text).*

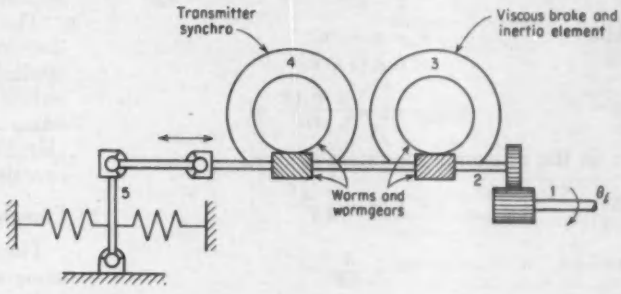



*FIG. 4. Early feed-forward system (British Admiralty, 1934) is of the type in Figure 3C. Viscous function of velocity and acceleration (3) modified input (1) to transmitter synchro (4) by causing shaft (2) to displace against springs (5), thus rotating synchro input shaft through correct compensating angle. Lag signal from viscous element was made to advance synchro by using opposite-hand worm gears. System was discarded because of high loading of input shaft.*

error. Most high-performance servos can be regarded as basically torque controllers in that the servomotor produces a torque which is a function of the error. Thus the error is essentially a function of the torque requirements of the load as dictated by the acceleration of the input member; i.e.,

$$\epsilon = f(p^2\,\theta_i) \qquad \text{where } p = \frac{d}{dt}$$

This expression may be modified if the servo is stabilized by velocity feedback, in which case there will usually be a substantial component of the error proportional to the velocity of the input member. In this case

$$\epsilon = f(k_1 p^2 \theta_i + k_2 p \theta_i)$$

Since the error is a function of $\theta_i$, it should be possible to derive from $\theta_i$ a feed forward of the necessary form. Such an arrangement is shown in Figure 3A. This is very similar to Figure 2, but derives the feed forward $\theta_f$ from an element $F$, which takes its input from $\theta_i$. The feed forward, as before, is taken to the input of element B. Since the feed forward originates in $\theta_i$, which is outside the loop, servo stability will not be affected. It would also seem that there is no reason why the entire input to element B necessary to keep $\theta_o$ in alignment with $\theta_i$ should not be supplied by $\theta_f$, the output of element $F$. The output from element A would then be zero, and its input, the servo error $\epsilon$, would also be zero.

This is in fact quite sound, since the main control is now by an open-loop system via elements $F$ and B, with the closed-loop round elements A and B performing a monitoring function in the presence of such irregularities as rapid changes of load, noise in the input signal, amplifier drift, etc. In practice, these imperfections make the closed-loop essential; the major input to element B comes from element $F$, so that the output of element A and hence the system error are much smaller than in the system shown in Figure 1.

To deduce the transfer function of element $F$ in Figure 3A, assume for simplicity that the system is stabilized by derivatives of error:

$$\theta'' = \frac{\theta_o}{B}, \text{ and } \theta_f = F\theta_i$$

But if $\theta_f$ is to supply the whole input required by element **B,**

$$\theta_f = \theta''$$

When the system error is zero $\theta_o = \theta_i$, so that in these conditions

$$F = \frac{1}{B}$$

The system shown in Figure 3A thus gives a theoretical solution to the problem of eliminating

the system errors of a closed-loop servo, without affecting its stability; it has been achieved by the use of a feed-forward term derived from $\theta_i$.

It is by no means essential to introduce the feed forward between elements A and B; Figure 3B shows an arrangement where it is brought to the input to element A. By reasoning similar to that for the case in Figure 3A, the conditions for zero error will be met where

$$F = \frac{1}{AB}$$

It is possible also to introduce the feed forward before the error-measuring device, as shown in Figure 3C.

In this case $\frac{\theta_o}{\theta'} = \frac{AB}{1+AB}$, so $\theta' = \frac{1+AB}{AB}\,\theta_o$

but $\theta' = \theta_i + F\theta_i$

so $\theta' = \theta_i\,(1+F)$

and $\theta_i\,(1+F) = \frac{1+AB}{AB}\,\theta_o$

In the zero-error condition, $\theta_i = \theta_o$,

so $1 + F = \frac{1+AB}{AB}$

and $F = \frac{1}{AB}$

which is the same as for the case of Figure 3B.

As stated, these general proofs are based on the simplifying assumption that the closed-loop servo is stabilized by derivative of error; the principle can be applied to any type of servo.

The main disadvantage of feed forward is that it does not reduce errors arising from external forces applied to the output member. Thus it will not reduce the errors due to wind gusts on a radar antenna or the throw-off of a gun mounting. The closed-loop servo must therefore be stiff enough to contain these forces independently of feed forward.

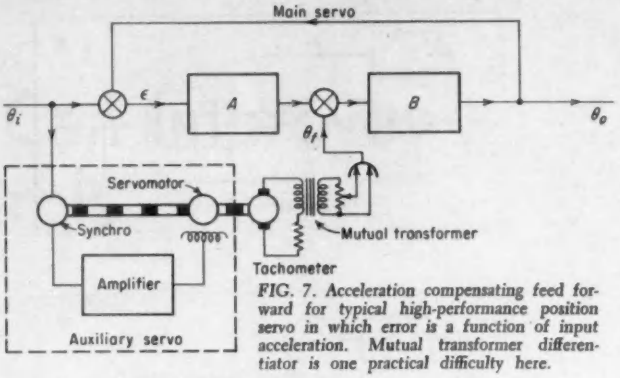



*FIG. 7. Acceleration compensating feed forward for typical high-performance position servo in which error is a function of input acceleration. Mutual transformer differentiator is one practical difficulty here.*

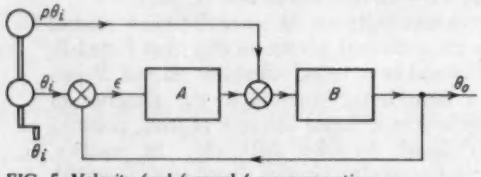



*FIG. 5. Velocity feed forward for compensation of velocity-stabilized position servos is impractical because of tachometer-generator nonlinearities.*

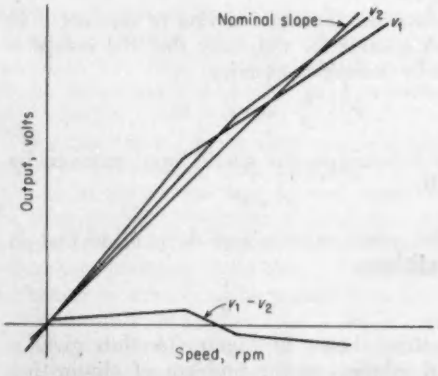



*FIG. 6. Nonlinearities in tachometer-generator outputs can produce differential errors of a few volts at high speeds when used as in Figure 5.*

## Developing practical feed forward

The idea of feed forward is by no means new and many attempts have been made over the years to realize its potential advantages. Probably the first recorded application of the principle was by a British Admiralty establishment about 1934. The device is shown in schematic form on Figure 4, and its operation is described in the caption. It is reported to have worked well, but was not taken beyond the experimental stage because of its bulk, and its torque demands on the source of $\theta_i$.

Attempts have been made to compensate for the large velocity errors which can arise in a well-damped position servo stabilized by velocity feedback. The straightforward approach shown in Figure 5 is perfectly sound in essence, but is impractical because of the differences of specific output (volts per rpm) and nonlinearities of even the best tachometer generators available at present. Whereas the variations of specific output between individual tachometer generators can be easily balanced, the nonlinearities present a more serious problem. Since the tolerance for variations from the true slope due to nonlinearity is generally of the order of 0.5 percent per generator, it is possible to have an error of as much as 2 or 3 volts between the two generators when they are running at the same speed at the higher end of their range. The proportion of this error applied to the servo leaves large residual errors, as shown in Figure 6, which make this method unrewarding.

As already stated, the typical all-electric, high-performance position servo is stabilized by a combination of phase-advance and lagging acceleration feed-

back, and this, together with a high loop-gain, gives a good approximation to the zero-velocity-error characteristic. The predominant error will therefore be proportional to the acceleration of the input member; i.e., $\epsilon \propto p^2\theta_i$, and an acceleration feed forward is required. (The greater part of Metropolitan-Vickers' work on feed-forward systems has been carried out to improve the performance of position servos with these characteristics.)

The most direct way to get the second derivative of $\theta_i$ would be to use an accelerometer driven directly by the input member. The main objections to this are:

- the torque requirements of the accelerometer drive, which can rarely be met by the low-power mechanisms providing $\theta_i$
- the low-level output provided by the pure accelerometer, necessitating amplification to bring the signal to a useful level

Another simple solution, using a tachometer generator whose output is electrically differentiated to provide the required acceleration signal, is subject to the first objection to the accelerometer, i.e., driving power requirement. It does, however, provide a usable signal level and applied experimentally to several servos, has made useful reductions in error when following a sinusoidal input.

To overcome the drive-power difficulty, the tachometer generator was driven by a small position servo following the main transmission of $\theta_i$, as shown in Figure 7. This is acceptable, provided that the auxiliary servo is of the zero-velocity-error type, is at

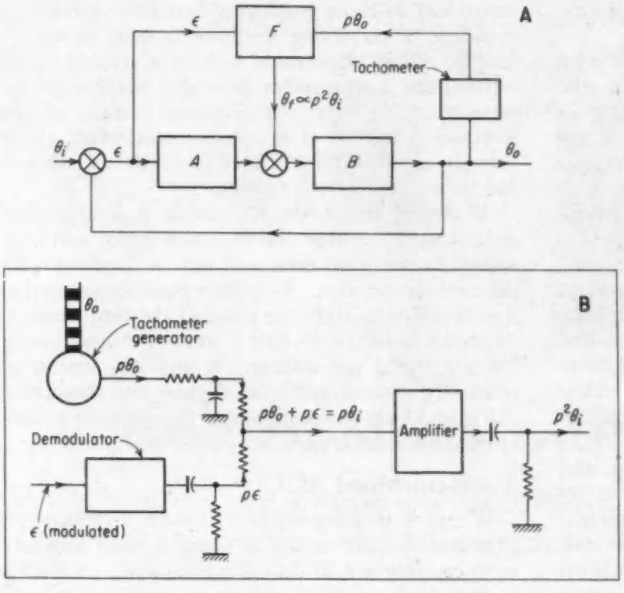



FIG. 8. The Acceleration Compensation Unit (ACU). A—In this system, the input signal is synthesized from the error and the output, so that the input shaft is not loaded. B—RC networks provide the necessary differentiation as explained in text.

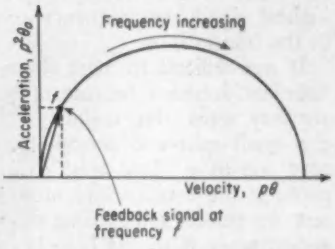



FIG. 9. Differentiation of RC networks is a function of frequency as shown, and must be compensated.

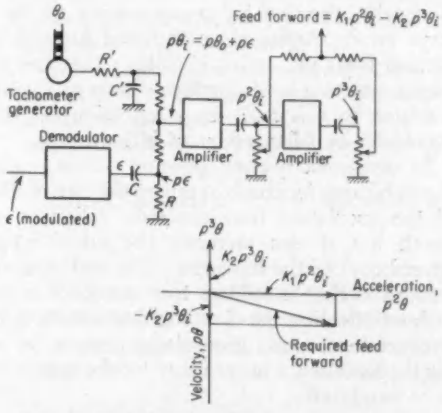



FIG. 10. Final ACU includes two compensations (R'C' and $p^3\theta_i$) for imperfect differentiation of RC networks.

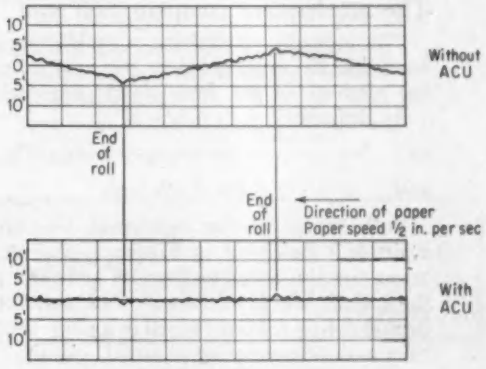



FIG. 11. Recording of error in typical servo with and without ACU.

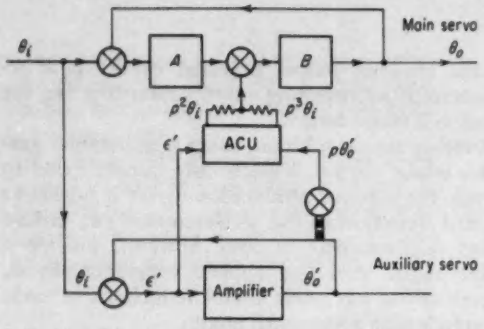



*FIG. 12. Self-contained ACU synthesizes feed-forward signal from the error and output signals of auxiliary servo of much higher response than main servo to be compensated.*

least critically damped, and has steady-state errors directly proportional to the acceleration of $\theta_i$. It must also have a natural frequency well above the highest significant frequency component appearing in the transmission.

It was difficult to meet these requirements with sufficient accuracy because of nonlinearities in the auxiliary servo, due mainly to frictional effects in the small split-field servomotors available. These gave rise to a "dead zone", causing the motor to pause at the maxima and minima of the sine-wave test movement, and causing the feed forward to disappear when it should have been at a maximum.

Notice that at this stage of development it was the practice to differentiate the tachometer-generator output by means of a "mutual transformer", since this gives a close approximation to true differentiation over a wide frequency range while the primary *current* is proportional to the signal. For this reason the primary winding was fed through a large resistance, in some cases pentode vacuum tubes. These transformers, however, were very heavy, large, and expensive, since they were required to function at frequencies as low as 0.1 cps, so they were abandoned in favor of RC circuits, which are smaller and cheaper. Moreover, while the differentiation obtained is inferior to that of the mutual transformer, means have been found for compensating for this.

Friction troubles with the small servomotor made it necessary to drop the scheme shown in Figure 7.

## The acceleration compensation unit

The difficulty of deriving a satisfactory feed forward directly from $\theta_i$ led to the next development, the synthesis of $p^2\theta_i$ from readily accessible signals.

By definition: $\epsilon = \theta_i - \theta_o$

so $\theta_i = \theta_o + \epsilon$

and $p^2\theta_i = p^2\theta_o + p^2\epsilon$

Both terms on the right-hand side are readily available. Referring to Figure 8, the $p\theta_o$ term is taken directly from a tachometer generator geared to the $\theta_o$ shaft, and is mixed with a $p\epsilon$ term obtained by demodulating the error signal in a phase-sensitive rectifier and differentiating in an RC circuit.

Because of its semicircular vector locus, Figure 9, the RC circuit's output will lag behind true differentiation by an angle dependent upon frequency. Thus the $p\epsilon$ signal will not be phased correctly with respect to the $p\theta_o$ signal. By arranging to give the $p\theta_o$ signal the same lag at any frequency that the output of the differentiating circuit has behind 90 deg of lead, the signals will be correctly phased with respect to each other. The simple RC integrating circuit shown in the $p\theta_o$ circuit in Figure 8 performs this function. Provided the two signals are correctly proportioned and phased, their sum will be equal to $p\theta_i$. The $p\theta_i$ signal is amplified and further differentiated to give a $p^2\theta_i$ signal, which is fed forward to the servo amplifier.

This device has become known as the "Acceleration Compensation Unit", or ACU, and has been widely and successfully applied to all-electric position servos and to those employing hydraulic drives.

Where a stabilizing feedback is used in an all-electric system, it is usual to take a velocity signal either from a tachometer generator coupled to the servomotor, or from the armature voltage of the servomotor itself if it is armature-controlled. This velocity signal is differentiated in an RC circuit and fed back to the servoamplifier.

As already stated, the RC circuit is an imperfect differentiator, so that the feedback signal and consequently the servo error will not be in phase with the acceleration of $\theta_i$. To obtain good compensation it is necessary to shift the phase of the feed forward. As shown in Figure 10, this is done by differentiating the $p^2\theta_i$ signal and adding $p^2\theta_i$ and $p^3\theta_i$ vectors to obtain the desired feed-forward phase and amplitude.

Figure 11 shows recordings of the errors in a zero-velocity-error servo with and without the ACU.

## A self-contained ACU

Where it is not possible to couple a tachometer generator directly to the $\theta_o$ shaft, a small auxiliary servo can follow $\theta_i$ to drive the generator. As shown in Figure 12, an ACU is used to synthesize a feed-forward signal from the $p\theta_o$ and $\epsilon$ terms of the auxiliary servo. Since this is derived from the same $\theta_i$ it is equally effective for compensation of the main servo error. Again, since the feed forward is now derived from $p\theta_o$ and $\epsilon$, it follows that the friction effects applying to the system shown in Figure 7 do not arise in this case, for a reduction of $p\theta_o$ must necessarily be balanced by an increase in $\epsilon$.

In zero-velocity-error position servos, increasing the stabilizing feedback improves the rate of damping of the oscillatory transient error following a step input; but it also increases the initial amplitude (overshoot) of the transient. The real value of feed forward is that it reduces this overshoot amplitude without affecting the damping rate. It thus permits a reduced error for a given decay rate; or, by increasing the feedback, a faster decay for the same transient error amplitude.

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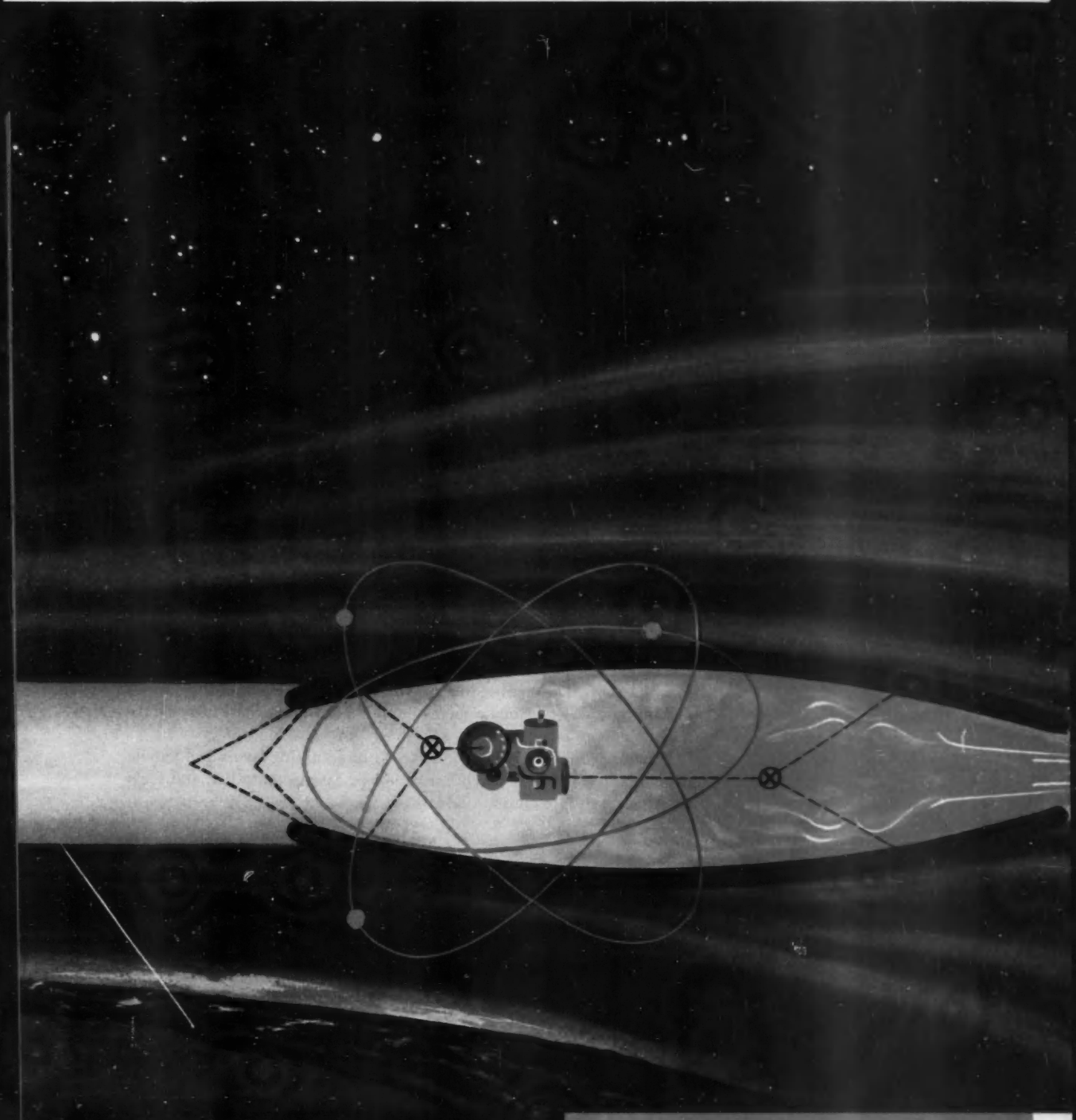

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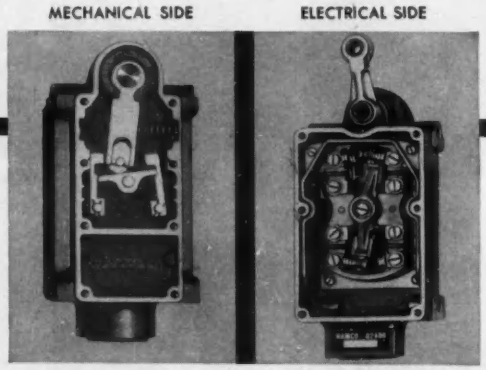

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# Step-and-Null System Controls Commutator Undercutter

**Timer-programmed coarse steps are nulled by a precision optical position servo in this system. It aligns insulating segments of motor commutators with slitting wheel for production-line undercutting.**

*L. W. KERBEY*
*E.M.I. Electronics, Ltd., England*

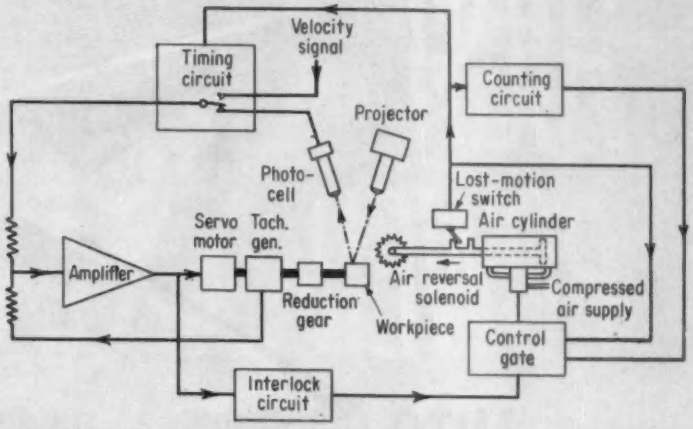


*FIG. 1. Moving coil vibrator unit scans the incident light beam over the commutator surface, to detect position of insulating segment relative to mean beam position.*

In a new system for undercutting the insulating segments on electric motor commutators, a commutator is rough-positioned to each segment by a program timer, then nulled by a scanning-type photoelectric sensor. Figure 1 shows the basics of the scanning system. A narrow slit in front of the light source is vibrated by a moving coil motor, and light reflected from the commutator surface is picked up by a photocell (Figure 2).

The system operates on the difference in reflectance between the copper commutator bars and the darker insulating segments. When an insulating segment is embraced by the vibrating slit image, reflected light from the commutator surface is modulated by the relative position of the insulating segment within the scanned area. Displacement of the insulating segment either side of the center position produces a modulation signal at the vibration (power-line) frequency. Amplitude of the signal is proportional to the displacement and its phase is dependent on its position left or right of center.

Stray light has no effect on the modulated signal unless the stray illumination is itself modulated at frequencies close to the scanning frequency. Since scanning is done at the power-line frequency, a photocell with a spectral response in the near-infrared band would prevent interference from any blue and near-ultraviolet fluorescent lighting systems. Interference from ordinary filament lamps is ruled out by their thermal capacity.

The resulting ac modulation voltage from the photocell is amplified to drive the control phase of a two-phase servomotor. Reduction gears couple the servomotor to the commutator workpiece. Correct phase connections of the voltage applied to the vibrator coil rotate the commutator to center the insulating segment within the image area when the line-frequency component of the modulated light becomes zero. In this position, however, an output signal at twice line-frequency is obtained, because two light pulses are received by the photocell during each complete scanning cycle. With the servomotor reference winding energized from the line-frequency, this double frequency signal has no effect on positioning.

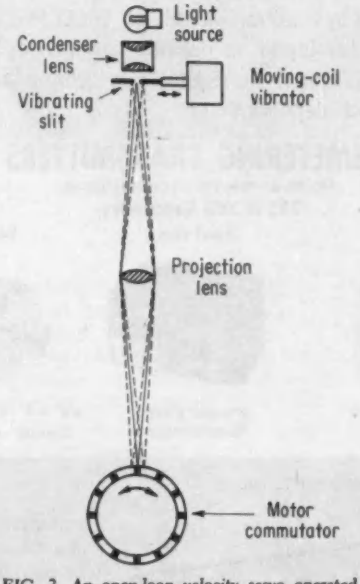


*FIG. 2. An open-loop velocity servo operated by a timer sets the coarse position of each segment within the scanning area of the beam. A closed-loop optical system aligns the insulating segment to the slitting saw to 0.002 in.*

When the servomotor reaches its null position, a slit is made on the insulating segment by a cutting wheel mounted in the same plane as the slit image. Accuracy of positional setting depends for a first order on the photocell sensitivity and amplifier gain. The commutator can be set to better than 6 minutes of arc.

## System operation

After the first slot to be cut is correctly aligned, a solenoid valve feeds an air cylinder, which advances the rotating cutting wheel along the insulating segment. A lost-motion switch trips at the end of the cutting stroke, reversing the air supply, registering a count in a counting circuit, and priming a timing circuit. The cutting wheel then retracts to its reset

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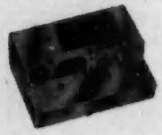

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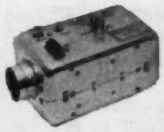

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position, resetting the lost-motion switch to its original position. This triggers the timing circuit and converts the amplifier and servomotor to a velocity system. The servomotor then rotates the commutator at a preset constant speed until the timer runs out. Correct setting of the speed during this time interval insures location of the next uncut segment within the scanning range of the split-image. At the end of the timer interval, contacts in the timer revert the system to a null servo and the optical system takes over to align the segment for the next cutting action.

To prevent premature or false cutting, the air valve is held off until alignment is completed, i.e., until the double line-frequency signal appears at the amplifier output when the servo nulls. An interlock circuit discriminates between the three amplifier output conditions—positive or negative phases of the line-frequency error signal, the twice-line-frequency signal appearing when copper segments only are scanned, and the twice-line-frequency signal present when the insulating segment is central in the scanning area. The twice-line-frequency signal appearing when the segment is correctly aligned is in anti-phase to that obtained when only copper portions of the commutator are scanned; it is detected in the interlock circuit to actuate the solenoid valve.

This cycle of events is repeated until all segments in the commutator—the number is set into the counter—have been cut. The counter then closes a gate and sets to standby.

A total operating cycle takes 1 sec, divided as follows:

| | |
|---|---|
| Coarse position | 0.20 sec |
| Nulling | 0.10 sec |
| Interlock time delay | 0.10 sec |
| Cutting stroke | 0.60 sec |

The overall cutting rate of one slot per sec allows one operator to supervise three such machines, each producing at a rate comparable to a skilled machinist.

Several such systems are in use for undercutting vacuum-cleaner motor commutators at the Perivale plant of Messrs. Hoover, Ltd. The operations are completely automatic from the time the armature is loaded into the machine until it is removed.

Acknowledgement is made to F. R. Ellory for guidance during the design and development of this system.

# Eddy Currents Brake Conductive Liquid Flow

**Throttling liquid flow by the eddy current principle can be practical and very simple, if the liquid is electrically conductive, experience on a sodium-cooled reactor proves. General design data are included.**

*W. S. De BEAR,*
*Atomics International*

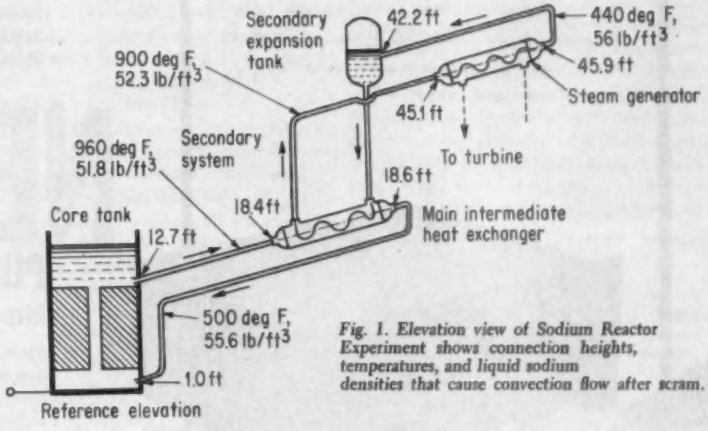



*Fig. 1. Elevation view of Sodium Reactor Experiment shows connection heights, temperatures, and liquid sodium densities that cause convection flow after scram.*

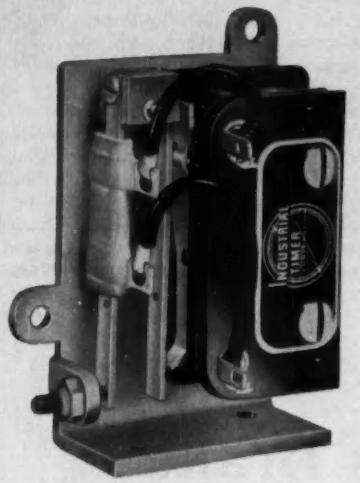
Emergency shutdown or "scram" in a nuclear reactor reduces heat generation in the core due to fission to 2 or 3 percent of maximum within a few seconds. However, in the Sodium Reactor Experiment (SRE, a sodium-cooled and graphite-moderated 20-megawatt reactor) the primary heat transfer loop involves elements at considerably different elevations, as in Figure 1; here convection heads would maintain as much as 15 percent of the initial flow rate in the liquid-sodium coolant after the same few seconds. Rapid temperature decays resulting from this wide variation between power-generation rate and coolant-flow after scram would mean exposing several important reactor components to large thermal transients. Analog studies plus several planned low-temperature scram tests verified that these thermal stresses would exceed the material yield strength in one component on a full-power scram.

Some sort of brake was needed, therefore, to throttle the coolant flow rate after scram. The reliability requirements are the usual difficult ones of a reactor's primary loop:

- no possibility of leakage
- invulnerability to radiation
- minimum operator attention
- minimum need for maintenance
- low pressure drop for normal reactor operation

Several braking methods were considered, and the electromagnetic eddy-current brake was selected for three reasons—it is extremely simple, it has no moving parts, and penetration of the main piping is unnecessary for its use.

The design of the brake units was based on original equations for the eddy-current drag on a spinning copper disc, established by R. Rudenberg in 1907 (Ref. 1). This work was modified by R. S. Baker (Ref. 2) to permit the evaluation of a pressure drop created by a strong magnetic flux



*These new developments are just two recent items added to our ever growing line of industrial timing devices which now exceeds 1,700 controls. If you would like more information about the line, drop us a note requesting our general catalogue.*

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## 10-20 Amp. Capacity—SNAP ACTION

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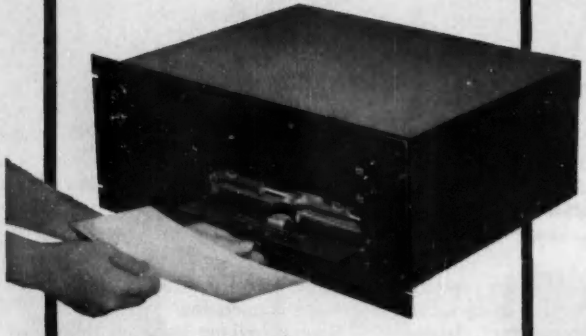
There's a wide choice of contacts, too: SPDT, DPDT, Double Break, Magnetic Blowout DC and others to match your needs.

This new, compact timer automatically compensates for ambient temperature changes, by using two parallel bi-metal strips. Longer life comes from the rugged, totally enclosed cast ceramic heater. And you can adjust your time cycle easily with a single screw.

Available in time cycles from 2 seconds to 5 minutes, the new Series TH Timers are the low-cost answer to switching in air conditioning, refrigeration, exhaust and heater controls, computers, lighting, and a host of other applications.

For complete information, write today for Bulletin #900.



# NEW! SIMPLIFIED PUNCHED CARD PROGRAMMER

## Direct Control from Programmer to Process!

Here's the simple, dependable method of applying true automatic control to most of your manufacturing and operational processes . . . *direct control* of up to 85 individual load circuits through as many as 30 separate functions . . . with permanent, convenient 5″ x 9″ Mylar* punched cards.

Operation from any switch closure makes this electro-mechanical card reader easily adaptable to a variety of control systems, including analog, digital, temperature, feed-back, photoelectric, time and many others. Already in use for a wide variety of industrial and military applications, these flexible units are easily modified to meet your particular requirement.

For more information, write for Bulletin #100.

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*Reg. T.M. du Pont

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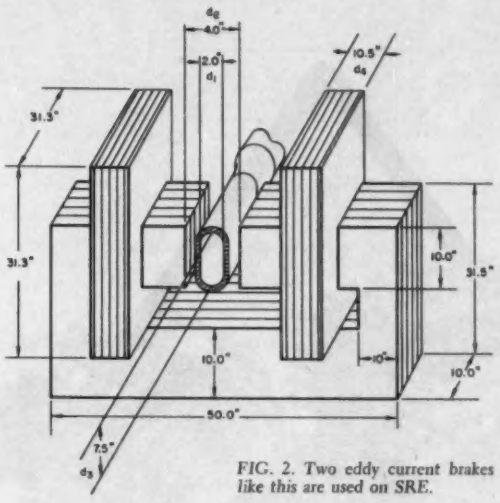



*FIG. 2. Two eddy current brakes like this are used on SRE.*

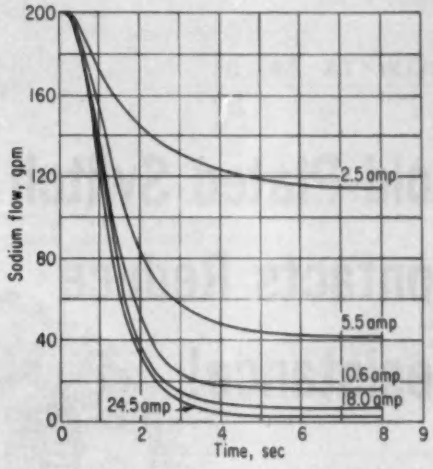



*FIG. 3. Flow vs. time curves measured on SRE for typical operating conditions show effectiveness of different total dc currents in brake coils.*

in a flowing conducting medium, in accordance with the following relationship:

$$\Delta P = \frac{8.5 \times 10^{-18} Q B_g^2}{r_l d_1} \times \left[ \frac{\frac{d_3}{d_4} + \frac{d_4}{d_3}}{\left(\frac{39.2 \times 10^{-3} Q}{r_l d_2}\right)^2 + \left(\frac{d_3}{d_4} + \frac{d_4}{d_3}\right)^2} \right]$$

where:

$\Delta P$ = pressure drop across brake throat (psi)
$Q$ = flow rate (gpm)
$B_g$ = flux density in liquid (lines per square inch)
$r_l$ = resistivity of flowing liquid (ohm-inches)
$d_1, \ldots d_4$ = dimensions of brake and throat section (inches) as shown in Figure 2.

This general statement is applicable to any conducting fluid. Its practicality as a method of flow control depends strongly on the resistivity of the fluid. The eddy-current brakes have proved eminently satisfactory for control of liquid sodium at 500 deg. F. Flow reduction against constant driving heads is rapid, effective, and exceptionally smooth and vibration-free.

**The SRE brake**

The SRE brake unit, Figure 2, is simply a heavy, laminated core of mild steel (laminated for ease of handling and fabrication only), with large copper coils mounted on the two pole pieces. The coils are connected in parallel to a 120-vdc emergency bus to insure availability in case of loss of normal power. Maximum coil current is 8-10 amps under the most severe operating conditions. The brake was designed to develop a dragging pressure of 0.3 psi (the approximate driving pressure due to convective head at full temperature gradient) at an equilibrium flow condition of 12 gpm. This value represents approximately 1 percent of normal flow at full power and is commensurate with the minimum post-scram power level.

Figure 3 shows brake performance under conditions approximating design values. A time constant of 3.7 sec was measured for the electrical R-L circuit at the design current of 10 amps per coil.

The two eddy-current brakes in the SRE are admittedly very large and heavy; but the complete design of these previously untried units, their fabrication, testing, and installation in the reactor plant were accomplished in just over four months. Weight and size reduction should be possible.

Experience at SRE encourages the feeling that the eddy-current brake principle may have great potential for controlling the flow of numerous difficult-to-handle liquid metals or other conducting media where high temperature, containment, corrosion, abrasion, or difficult installation environments may present special problems with more conventional equipment, whether in the nuclear field or process industries.

REFERENCES

1. *ENERGIE DER WIRBELSTROME IN ELEKTRISCHEN BREMSEN UND DYNAMOMASCHINEN*, R. Rudenberg, "Sammlung Elektrotechnischer Vortrage", (Stuttgart, Germany: Ferdinand Enke, 1907), No. 10, p. 269.
2. *CALCULATION OF DEVELOPED PRESSURE AND FLUID POWER IN LINEAR POLYPHASE INDUCTION LIQUID METAL PUMPS*, R. S. Baker, Mine Safety Appliances Co. Technical Report 48, March 24, 1956.

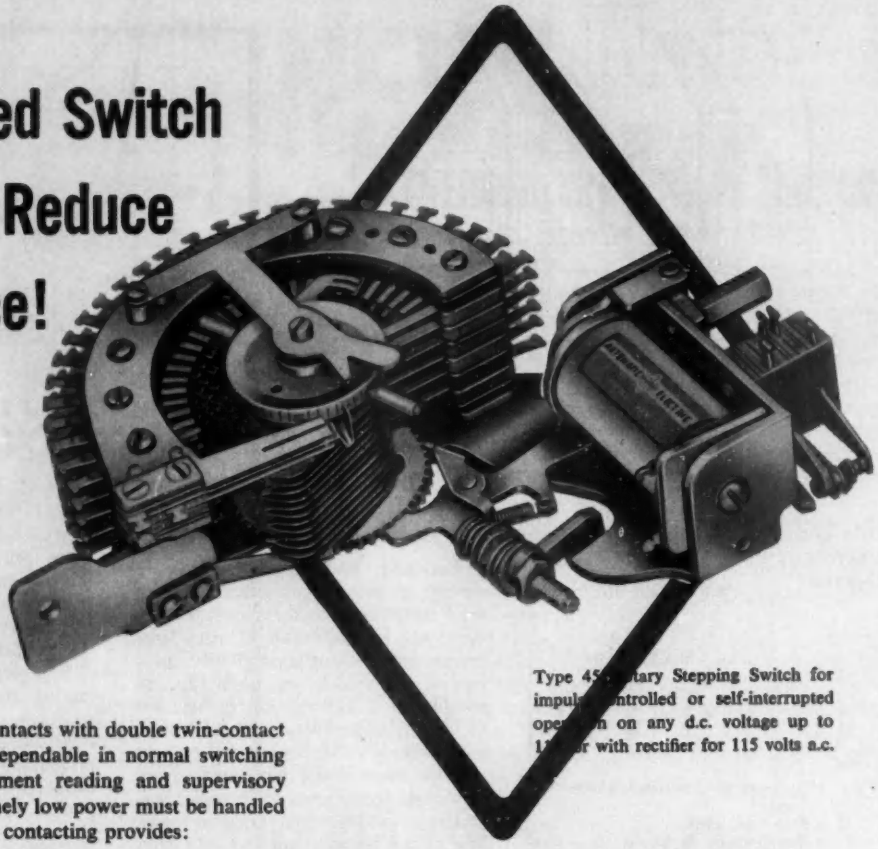
# A Wide-Range Sampler with Zero-Order Hold

*RICHARD E. ANDEEN, Northwestern University*

**Full details on a 0.2-to-2,000-cps sampler that can be very helpful for studying sampled-data control systems.**

Analog computer studies of sampled-data control systems can be made a lot easier by a flexible, wide-frequency-range sampler. The electronic sampler and zero-order-hold unit to be described was built with two synchronous sampling channels to study multiple sampler control systems. It has a sampling frequency range of 0.2 to 2,000 cps, with less than 10 deg phase shift at the highest frequency. The wide range is made possible by two features—sampling and holding operations are combined in a special

# Gold-Plated Switch Contacts Reduce Resistance!



Type 45 ...tary Stepping Switch for impul...ntrolled or self-interrupted ope...n on any d.c. voltage up to 1...r with rectifier for 115 volts a.c.

Standard base-metal contacts with double twin-contact design are absolutely dependable in normal switching circuits. But in instrument reading and supervisory functions, where extremely low power must be handled reliably, precious-metal contacting provides:

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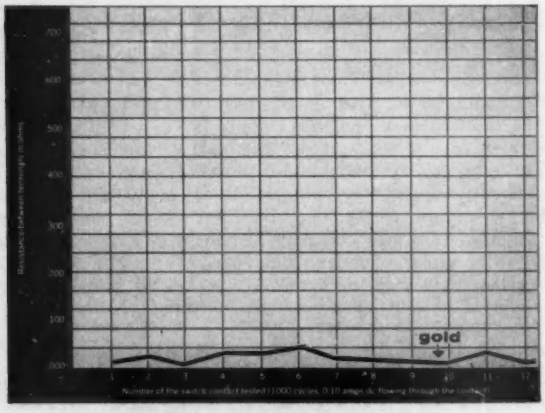
- *freedom from spurious potentials which can be set up by base-metal contacts*

That is why instrument engineers specify gold-plated contacts for thermocouple monitoring and other low-power-level circuits – strain gauges – computers – and infrequently operated devices.

Precious-metal contacting costs more, of course. But with Automatic Electric's custom designing, it is not as expensive as you might think; on either Type 44 or Type 45 Switches, you can specify precious-metal contacts for instrument circuits only, with standard contacts handling the less critical circuits.

For full information on the use of stepping switches–*with or without* precious-metal contacts–ask for Circulars 1641 and 1698. Write: Automatic Electric Sales Corporation, Northlake, Illinois. *In Canada:* Automatic Electric Sales (Canada) Ltd., Toronto. *Offices in principal cities.*




Graph indicates resistances between terminals with gold-plated contacts. Measurements made under heavy vibration.

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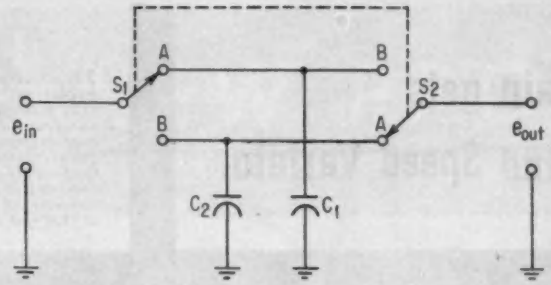



*FIG. 1. Switching and holding scheme used in electronic sampler.*

switching arrangement; and all switching is done electronically.

The switching arrangement, which combines the operations of sampling and holding, is simplified in Figure 1. The input voltage to the switching circuit is a continuous voltage, and the output voltage is a staircase-type voltage. During the first sampling period the switches $S_1$ and $S_2$ close to the terminals marked *A*. Holding capacitor $C_1$ charges up to the voltage of the input during the first sampling period. At the beginning of the second sampling period the switches are connected to the terminals marked *B*, where they remain during the second sampling period. Then the capacitor $C_2$ charges, while $C_1$ is connected to the output to provide a constant output voltage equal to the input voltage at the instant just before the switching occurs. In each sampling period, the roles of $C_1$ and $C_2$ reverse.

To perform the switching at relatively high frequencies the arrangement shown in Figure 1 was implemented electronically. Cathode-follower buffer amplifiers prevent the output capacitor from discharging.

A circuit diagram of a complete sampling and holding channel is shown in Figure 2. An external square-wave generator controls the switches. The sampling frequency is twice the frequency of the external square-wave voltage, which is amplified and inverted by the circuit in Figure 3 to provide two clock voltages, *A* and *B*, of plus and minus 50-volt square waves 180 deg out of phase.

The electronic switches (V1 and V2, V3 and V4) are 12AU7 vacuum tubes connected back to back. These provide a low impedance to current when the clock voltage applied to the grids is positive, and a very high impedance when the grid voltage is negative. The grid-to-cathode voltage of the 12AU7 tubes at the input is approximately equal to the clock voltage plus the voltage on the holding capacitor. This restricts the input voltage to plus or minus 25 volts, to prevent the tube's exceeding its grid-voltage rating.

The cathode follower 12AT7's are selected for low grid current, to insure a high input impedance and consequently a high holding-circuit time constant. The power stage, another cathode follower, is designed to deliver an output voltage of plus and minus 40 volts to a 10,000-ohm output load without appreciable attenuation. This means that the unit can be connected to three potentiometers at the same time.

In the unit built, one clock circuit drives two switching circuits. Power supplies are not shown, but 33 milliamps are required from both the positive and negative 300-volt sources. An analog computer power supply can provide these voltages.

The frequency selector is set to the setting of the external square-wave generator. This adjusts the holding capacitors to produce minimum phase shift compatible with good holding characteristics for the frequency range of interest. The undesired phase shift introduced by the holding capacitors (distinct from that due to the sampling) is never more than 10 deg at the highest frequency of the selector setting. Holding capacitor values were selected by experimentation.

| Frequency range, cps | Holding capacitor, mfd |
|---|---|
| 320 -1,000 | 0.001 |
| 100 - 320 | 0.0029 |
| 32 - 100 | 0.0085 |
| 10 - 32 | 0.026 |
| 3.2 - 10 | 0.073 |
| 1 - 3.2 | 0.23 |
| 0.32- 1 | 0.70 |
| 0.1 - 0.32 | 2.10 |

The balance control zeroes the output when the input voltage is zero. The level control adjusts for differences in the bias levels on either side of a channel. The phase control adjusts differences in the dynamic characteristics of the two sides due to tube and capacitor tolerances, and is not very critical.

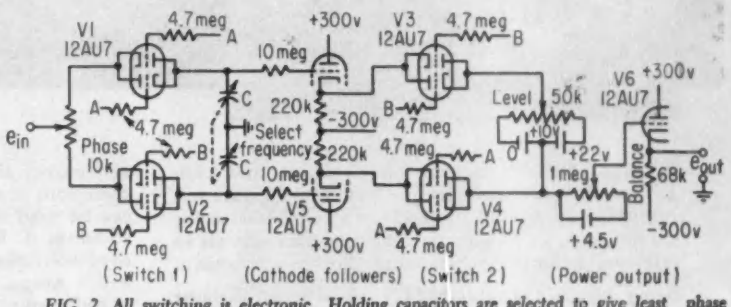



*FIG. 2. All switching is electronic. Holding capacitors are selected to give least phase shift (see text). Drive voltages A and B are provided by circuit in Figure 3.*

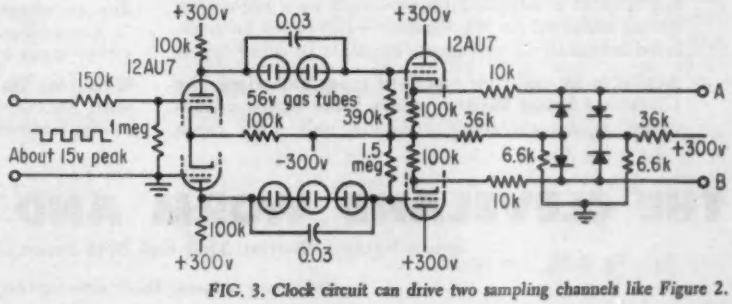
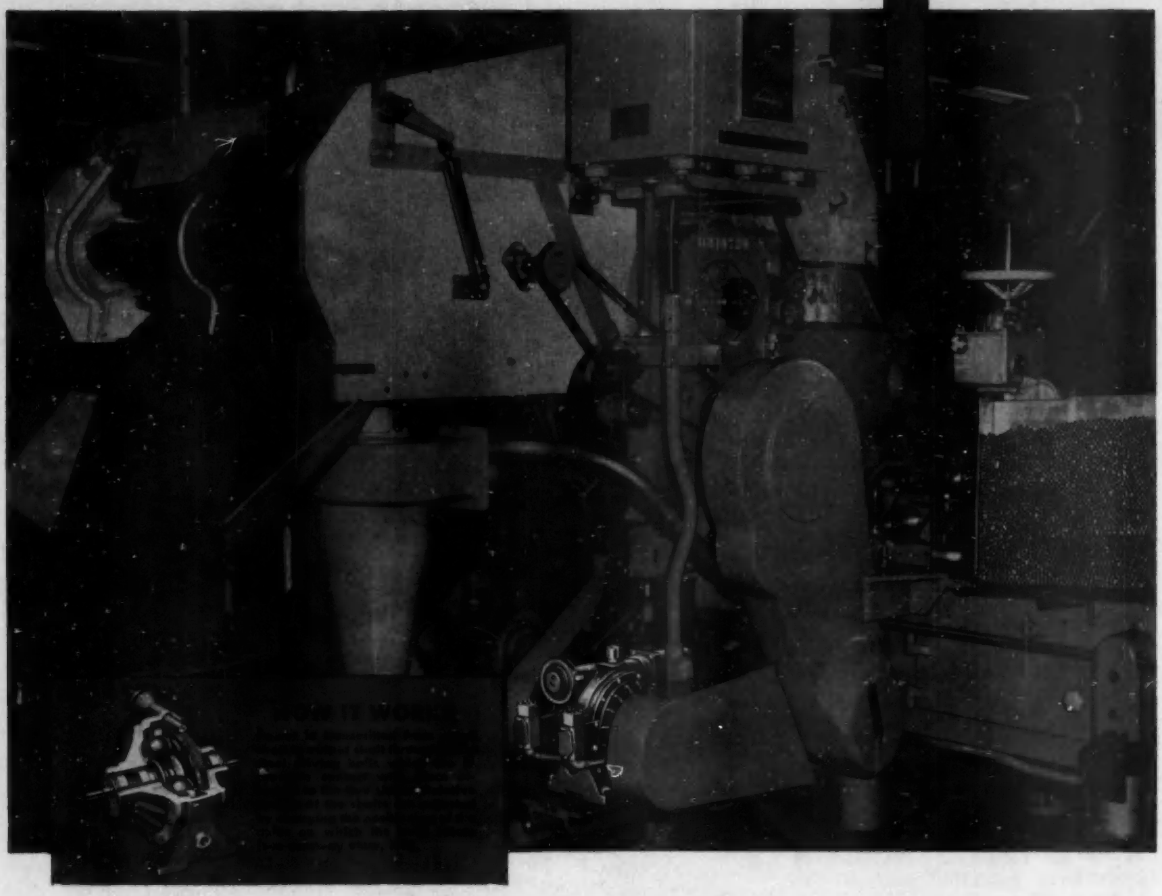



*FIG. 3. Clock circuit can drive two sampling channels like Figure 2.*

# *AccuRay* electronic brain gets muscle power from Cleveland Speed Variator

*The electronic control mechanism of this cigarette machine, known as the AccuRay cigarette gage controller, built by Industrial Nucleonics Corp., Columbus, Ohio, employs Cleveland Speed Variator size 4K4, driven at 1200 rpm input.*



NATIONALLY famous for checking and controlling the making of Chesterfield cigarettes, AccuRay depends on a Cleveland Speed Variator for the delicate job of adjusting the tobacco feed rate in response to impulses from the gaging mechanism.

Being infinitely variable, the Cleveland Speed Variator gives stepless speeds over a full 9:1 range—from ⅓ to 3 times input speed. Output speed on this application is adjusted automatically by a regulating motor mounted on the Variator—but could be regulated manually or by remote controls of other types.

Available in eighteen standard types and sizes, the Cleveland Speed Variator offers these major advantages: 1. An extremely compact unit with input and output shafts in line and rotating in the same direction; 2. Almost any input speed up to 1800 rpm can be used—either clockwise or counterclockwise rotation; 3. Rated for constant horsepower output over a 9:1 range, or for constant output torque with a 6:1 range; 4. Infinitely variable over the entire speed range; 5. Rapid response to speed change, precise adjustment, and accurate maintenance of speed settings; 6. Long life and minimum maintenance due to absence of belts or complicated linkages; 7. Ample bearing support for overhung pulleys on either input or output shafts.

Write for Bulletin K-200 for detailed description with photographs, sectional drawings, rating tables and specifications.

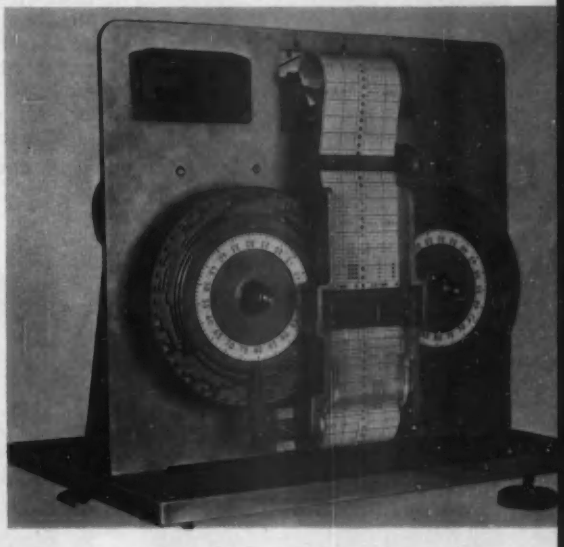
## THE CLEVELAND WORM AND GEAR COMPANY

Speed Variator Division, 3260 East 80th Street, Cleveland 4, Ohio

*Subsidiary of Eaton Manufacturing Company*

# NEW PRODUCTS

## ANALOG-TO-DIGITAL RECORDER
### runs 1 year on 6 volt dry cell.



Photos at the right show front and rear views (case removed) of a brand-new battery-operated analog-to-digital recorder, the Model 1542 ADR.

The instrument converts an analog input, in the form of a shaft position, into a permanent digital record in the form of a punched paper tape. This tape, a sample of which is shown below, is in four-position binary-decimal code, and can be read visually or translated into punched card or standard computer tape form for automatic processing. Digital values may be read directly from the numbered code discs on either side of the tape. One reads from 0 to 99; the other, from 100 to 10,000. Recordings may be made on demand or at any preset clock-controlled interval.

Its battery operation makes the device suitable for remote installations where no commercial power is available. Power consumption is such that with a 15-min readout interval, it will operate for a full year on a 6-volt dry-cell battery. At this same speed, a single roll of tape will last for a year and a half.

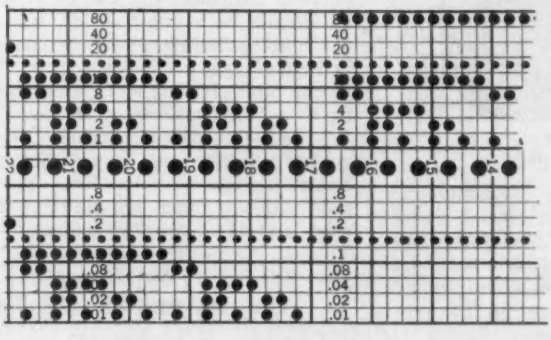
There are three general areas of application:

- Direct-motion recording—coupled with a suitable cable, drum, and float assembly, the ADR becomes a digital level recorder.
- Electrical signal recording—coupled with an amplifier, servomotor, and potentiometer, it becomes a complete logging system for temperatures, pressures, humidities, etc.
- Pulse-vs.-time recording—combined with a solenoid and ratchet wheel, it may be used to count pulses during any given time interval.

The two code discs, which make the actual conversion, feature a unique gearing arrangement that completely eliminates the ambiguity problem. Readout is accurate to the nearest half-count, or one part in 20,000.

Telemetering contacts (visible in the rear view) are supplied on the ADR as standard equipment. This parallel output, also in binary-decimal form, represents readings from 0000 to 9999.

Other features of the ADR include: an input-torque requirement of less than ¼ oz-in.; an ambient temperature range of minus 40 to plus 50 deg C; a drip-proof, weatherproof enclosure (not shown in either photo); and complete corrosion-resistant construction. For applications where commercial power is on hand, a 115-vac model is also available.




As an accessory, the manufacturer offers an automatic translator that will convert a 30-day record of 15-min-interval tape into punched cards in 20 min. A single battery-operated ADR sells for approximately $500.—Fischer & Porter Co., Hatboro, Pa.

Circle No. **200** on reply card

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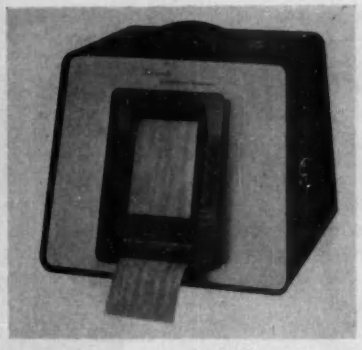
## NEW PRODUCTS

# DATA HANDLING & DISPLAY



### PORTABLE MONITOR

Pictured is the Model RE 3303-00 Operations Monitor, a portable instrument that will record up to 30 channels of on-off, open-shut, pulse, or event-type of information. Each event is shown in a time relationship to all other events. Electric writing produces an instantaneous, dry, and permanent record. Maximum chart speed permits resolution of event durations as small as 0.004 sec.—Brush Instruments Div. of Clevite Corp., Cleveland, O.

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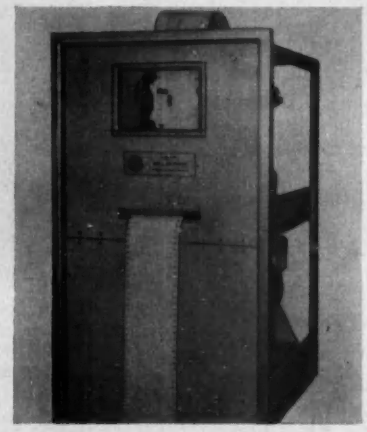


### HIGH PRINTOUT RATE

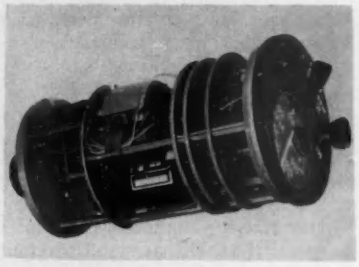
The Model 3260 Alphanumeric Printer, an integrally housed drum-type printer and electronic storage and control system, accepts data from any source of digital information. Suited for rack or desk mounting, the unit features a maximum possible printout rate of 48,000 digits per min. An exclusive print wheel design affords tailoring of type fonts to individual requirements and can be supplied with up to 40 columns of numerical or alphabetical characters. Type faces are made of stellite and printing is on multiple-copy fanfold paper with standard ribbon.—Potter Instrument Co., Inc., Plainview, N. Y.

**Circle No. 202 on reply card**

### ANALOG-DIGITAL LINK

A new family of high-reliability analog-digital computer linkage systems features compact construction and low power consumption. A typical system, the Model 4.030, links an IBM 700 series EDPM and an EAI analog computer by means of 20 analog-to-digital and 10 digital-to-analog information channels. To time-share a single analog-to-digital converter, the system uses a 20-channel, solid-state, analog multiplexer. More than 400 conversions per sec can be made on any channel with a conversion accuracy within 0.05 percent. For greater programming flexibility and to facilitate testing, there are provisions for manual-data entry to all 30 information channels.—Electronic Associates, Inc., Long Branch, N. J.

**Circle No. 203 on reply card**



### 44-OZ PACKAGE

Called a launch range computer, this compact system is designed to aid pilots in calculating the distance from an airplane to a target at any time. It electromechnically solves a problem in triangulation previously performed by the pilot. Its first application will be to aid in launching air-to-ground missiles. Components include two control transformers, a servomotor, transistor-magnetic amplifier, gear train with slip clutch and pushbutton reset, and an illuminated indicator.—Thomas A. Edison Industries, McGraw-Edison Co., West Orange, N. J.

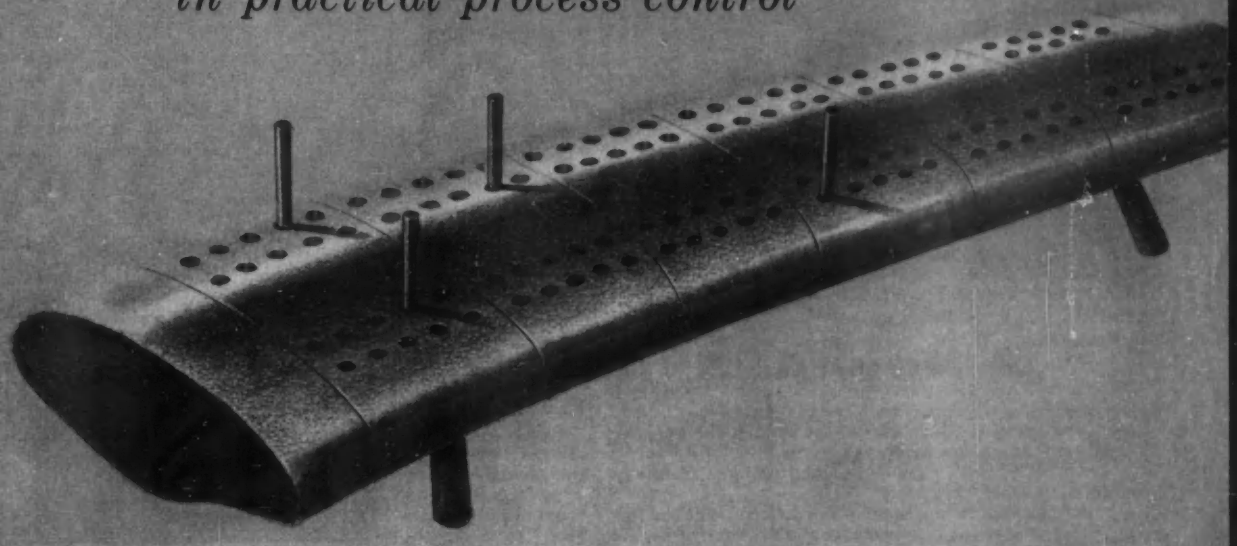
**Circle No. 204 on reply card**



CIRCLE 96 ON READER-SERVICE CARD →

# SEVEN GIANT STEPS FORWARD

*in practical process control*



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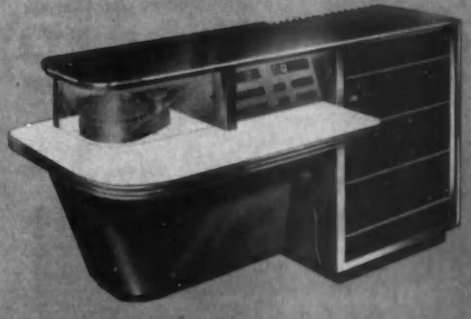

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A Subsidiary of CHANCE VOUGHT AIRCRAFT

# A New Addition

The model 1016A is the newest addition to the growing Bryant line of standard magnetic storage drums. Like other Bryant drums, it can be provided with custom-designed patterns of storage, and recirculating register tracks.

A full line of Bryant standard or special magnetic read/record heads meets the varying requirements of all computer manufacturers.

The exclusive foolproof Bryant head-setting design means real economy for original set-ups or change-overs.

Every leader in the electronics field has benefited from Bryant's 25 years of experience in ultra-high-speed precision rotating equipment.

**Features:**

- 10" Diameter by 16" long magnetic surface. (cabinet dimensions 25 x 25 x 35")
- Guaranteed accuracies of drum run-out to .00010" or less.
- Integral drive-Bryant precision motors (900 to 3600 RPM).
- Capacity over 1,500,000 bits.
- Up to 350 KC.
- Accommodates up to 20 magnetic read/record heads per inch with standard designs.
- Precision ground high density magnetic oxide coating. (Another Bryant exclusive)
- Super precision ball bearing suspension.
- Vertical mounting for trouble-free operation.

**Special Models:** If your storage requirements cannot be handled by standard units, why not let Bryant assist you in the design and manufacture of custom-made drums? Available speeds from 60 to 120,000 R. P. M., with storage up to 6,000,000 bits.

**BRYANT COMPUTER PRODUCTS DIVISION**

P. O. Box 620-L, Springfield, Vermont, U. S. A.

DIVISION OF BRYANT CHUCKING GRINDER CO.

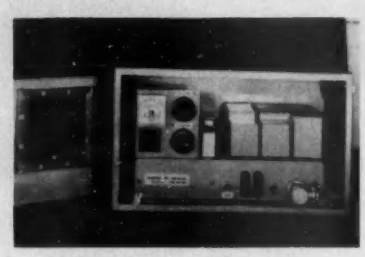
CIRCLE 97 ON READER-SERVICE CARD


## NEW PRODUCTS

### HIGH RELIABILITY

A recently-developed transceiver, called "Telescan", can multiplex as many as 28 signals over one pair of low-rate telegraph hardwires. The unit transmits and receives both metering and control signals bidirectionally or in a loop. The transmission rate of five pulses per sec at 120 vdc and 1 ma is well within the limits of this low-cost wire. Magnetic switch scanning eliminates friction and arcing at the switches and reduces motor load to approximately that of an electric clock.—Automatic Control Co., St. Paul, Minn.

**Circle No. 205 on reply card**



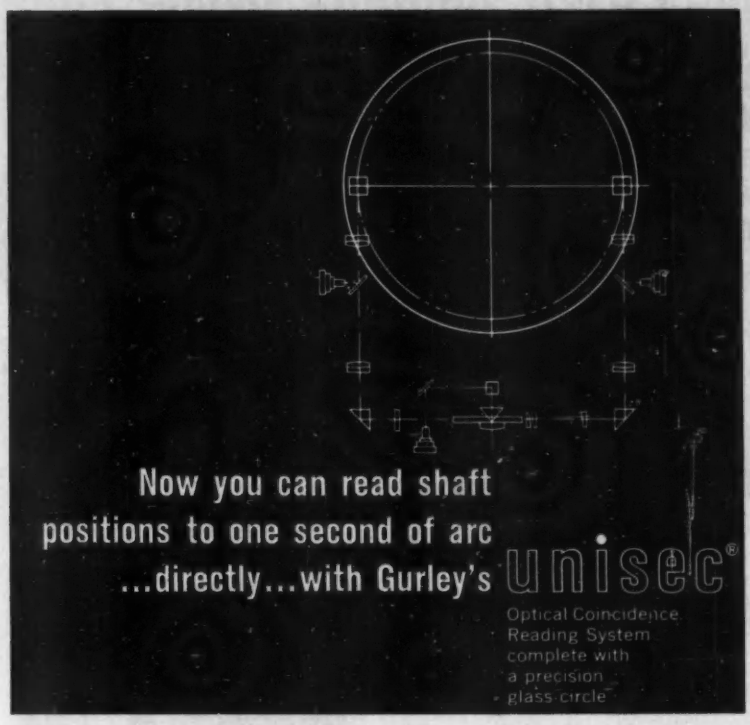
### REGISTERS TOTAL FLOW

Photo shows the internal arrangement of a new electronic flow-measuring system that boasts a long-term accuracy of 99.75 percent. Unit is designed to compute, integrate, and read out total flow of gas or liquid. Temperature and pressure transducers that provide the input information may be located up to one mile from the housing. Components include magnetic amplifiers, silicon diodes, and transistors. Unit has a speed of response of 0.03 sec and draws 15 watts at 95-120 volts, 60 cps.—Computers, Inc., Houston, Tex.

**Circle No. 206 on reply card**

### PLUS . . .

(207) **Ferranti Electric Inc.**, Hempstead, N. Y., has introduced the TR7, a self-contained **tape reader** suitable for reading five-, seven-, or eight-level tape at speeds up to 1,000 characters per sec. . . . (208) A readout **form printer** with a 12-decade capacity and an automatic form ejector has been developed by the **Electronics Div. of Clary Corp.**, San Gabriel, Calif. . . . (209) The new D-Pak constant-voltage supply is now standard equipment on a new line of **circular chart recorder-controllers** available from **Daystrom-**




Now that the industrial micromanipulator and the binocular microscope have been drafted from the laboratory—to help master the minuscule in industry—the ever-growing emphasis is on ultra-precision.

Each day there are increased industrial demands for tolerances so close that a reading microscope is needed to observe and check them. The success of many critical operations depends upon extreme tooling accuracy. But, as allowed tolerances grow vanishingly small, the cost of attaining specified precision tends to skyrocket. So too, as any modern precisionist can tell you, do the problems and frustrations!

Tooling accuracy, of course, is founded on the flat plane, a true perpendicular to it, and a linear measurement standard. *Now, an ingenious new instrument brings optics to the aid of industrial precision at a point in tooling operations where costly error can be forestalled—in initial positioning.*

**Extraordinary precision ... with optics**

A new device—called UNISEC—from W. & L. E. Gurley, makes extraordinary precision in angle reading conveniently available. It thus helps cut the costs that soar when initial inaccuracy reproduces its errors in ensuing work.

UNISEC consists of an Optical Coincidence Reading System and a Precision Glass Circle. The device actually reads the 6-inch circle to *one second of arc*—directly. It uses the principle of reading both sides of a circle at once to remove eccentric error.

**Precision through image coincidence**

The latest of a long Gurley family line of ultraprecision equipment, UNISEC will read the angular position of a rotatable shaft at rest *with a degree of precision obtainable otherwise only with an optical reading theodolite.* It can be attached to any rotatable shaft where highly precise positioning is desired. Turning the sighting device from base point to an object indicates the amount of angle between. On a clinometer, for example, it measures deviations from the horizontal.

Readings from the optically flat crown glass circle with its 2160 graduations are viewed through a microscope eyepiece which swivels 360 degrees to allow reading from any stance. The images of graduations taken from opposite sides of the glass circle are made to coincide in the reading microscope. Movement of a deviating prism system makes this possible. Measuring the position of the deviating prism makes possible the highly accurate angular reading.

Special eyepieces and units for screened projection at high magnification may be obtained. Special Coincidence Reading Systems, using larger circles and housings, add versatility to this device. UNISEC is one of a host of products studied, developed and manufactured by Gurley for science and industry. It has been widely welcomed at a time when the amount of permissible variance from a standard has already become vanishingly small.

**Gurley's 114 years of experience**

During 114 years of experience in optics the Gurley group have developed and made precision instruments ranging from surveying instruments to modern hydrological, meteorological and other engineering equipment; analog-digital converters; components produced by high precision photographic methods; as well as lenses, prisms, reticles and divided circles of the highest accuracy. (Also, though commonly thought of as surveyors' tools, Gurley transits and levels perform optical tooling in aircraft jig construction and solve many other difficult industrial aligning problems.)

*A bulletin illustrating the how and why of* UNISEC *is yours for the asking.*

**W. & L. E. GURLEY**
**INDUSTRIAL DIVISION**
**TROY, NEW YORK**

W. & L. E. GURLEY • 537 FULTON STREET • TROY, NEW YORK

**Please send details on the new UNISEC Coincidence Reading System**

Name_____

Title_____

Organization_____

Address_____

City_____ State_____

THE MOSELEY

AUTOGRAF
trade mark

X - Y - T* RECORDER

A direct writing, low frequency oscillograph for:

- X-Y RECORDING
- PLOTTING ONE VARIABLE VS TIME

With appropriate accessories will:

- PLOT IDENTIFIED POINTS FROM TAPE OR CARDS
- READ OUT CONDUCTING CURVES
- AUTOMATICALLY PRODUCE GAIN-FREQUENCY RECORDS

MODEL 3 S
8½" x 11" Recording Area
Y = 3.5 MV to 500 volts
$1300
X = 5 MV to 500 volts (11 steps) or 5, 10, 50, 100, 500 seconds

MODEL 2 S
11" x 17" Recording Area (Vacuum Grip)
Y = 15 MV to 100 volts (10 steps)
$1925
X = 7.5 MV to 150 volts or 7.5, 15, 75, 150, 750 seconds

* with TIME BASE

All models illustrated feature:

- Isolated servo-actuated drives for each axis
- Full range zero set and zero suppression
- Input filters and stepless range controls
- 200,000 ohms/volt input resistance
- One second or less for full scale deflection
- Better than 0.25% accuracy with 0.1% resetability

MODEL 6 S
AUTOMATIC FRAME ADVANCE
10" x 10" Recording Area (Vacuum Grip)
Y = 5 MV to 100 volts (10 steps) or 5, 10, 50, 100, 500 seconds
$2750
X = 5 MV to 100 volts (10 steps)

*All prices f.o.b. factory. Prices and specifications subject to change without notice.*

Call our sales representative in your area or write direct for additional information.

F. L. MOSELEY CO.

409 N. FAIR OAKS AVE., PASADENA, CALIFORNIA

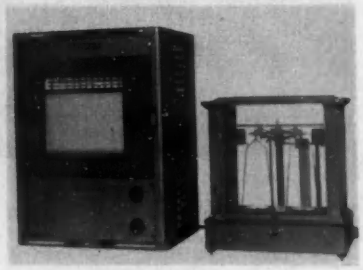
CIRCLE 99 ON READER-SERVICE CARD

## NEW PRODUCTS

**Weston Industrial Div. of Daystrom, Inc.**, Newark, N. J. . . . (210) **Digitronics Corp.**, Albertson, N. Y., has recently delivered the first prototype of an **electronic multiplier** capable of multiplying an eight-digit variable by any one of five constant six-digital multipliers in an average time of 0.0007 sec.

Circle No. **207**, **208**, **209**, or **210** on reply card

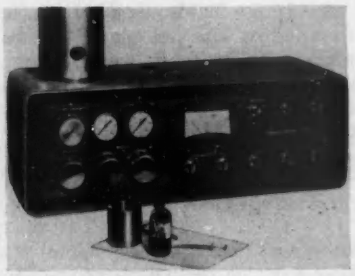
## RESEARCH, TEST, & DEVELOPMENT



### ANALYTICAL BALANCE

The instrument shown above is a new automatic-recording analytical balance that simultaneously records both weight and temperature against time, on a single chart. For thermogravimetric analysis, sample can be suspended from the balance and weight in a furnace. Accuracy is within 1/10 mg; maximum capacity is 200 grams.—Wm. Ainsworth & Sons, Inc., Denver, Colo.

Circle No. **211** on reply card



### NEEDS NO HELIUM

Maker claims that the Model 208 Vapor Fractometer, shown here, is the first commercial instrument of its kind that offers a flame ionization detector as standard equipment. It is

CIRCLE 100 ON READER-SERVICE CARD →

# Lambda Power Supplies have been the first choice of engineers in every independent poll

*The only power supplies guaranteed for 5 years*

This unprecedented five-year guarantee is the strongest proof of consistent trouble-free power supply performance ever offered. It is bolstered even further by a series of independent surveys which prove that Lambda equipment is preferred by more than 50% of the engineers who specify power supplies.

## CHECK LIST: LAMBDA REGULATED DC POWER SUPPLIES

| Model | Style | Voltage Range (VDC) | Current Range (MA DC) | Regulation Impedance Ripple (Table I) | 6.3 VAC Output (Amps) | Meters | Output Voltage Control | Output Terminals | Size Weight (Table II) | Price (U.S. and Canada) F.O.B. Factory College Pt., N. Y. |
|---|---|---|---|---|---|---|---|---|---|---|
| **REGULATED POWER SUPPLIES—RACK MOUNTING** | | | | | | | | | | |
| **TRANSISTORIZED** | | | | | | | | | | |
| LT-1095 | Rack | 0-32 | 0-1000 | A | — | None | Rear | Rear | S-1 | 285.00 |
| LT-1095M | Rack | 0-32 | 0-1000 | A | — | 2½" rect | Rear | Rear | S-1 | 315.00 |
| LT-2095 | Rack | 0-32 | 0-2000 | B | — | None | Rear | Rear | S-1 | 385.00 |
| LT-2095M | Rack | 0-32 | 0-2000 | B | — | 2½" rect | Rear | Rear | S-1 | 385.00 |
| **TUBE REGULATED** | | | | | | | | | | |
| C-280 | Rack | 0-280 | 0-200 | C | 10A | None | Rear | Rear | S-2 | 184.50 |
| C-280M | Rack | 0-280 | 0-200 | C | 10A | 3½" rect | Rear | Rear | S-2 | 214.50 |
| C-281 | Rack | 125-325 | 0-200 | C | 10A | None | Rear | Rear | S-2 | 159.50 |
| C-281M | Rack | 125-325 | 0-200 | C | 10A | 3½" rect | Rear | Rear | S-2 | 189.50 |
| C-282 | Rack | 325-525 | 0-200 | C | 10A | None | Rear | Rear | S-2 | 189.50 |
| C-282M | Rack | 325-525 | 0-200 | C | 10A | 3½" rect | Rear | Rear | S-2 | 199.50 |
| C-480 | Rack | 0-280 | 0-400 | D | 15A | None | Rear | Rear | S-2 | 259.50 |
| C-480M | Rack | 0-280 | 0-400 | D | 15A | 3½" rect | Rear | Rear | S-2 | 289.50 |
| C-481 | Rack | 125-325 | 0-400 | D | 15A | None | Rear | Rear | S-2 | 244.50 |
| C-481M | Rack | 125-325 | 0-400 | D | 15A | 3½" rect | Rear | Rear | S-2 | 274.50 |
| C-482 | Rack | 325-525 | 0-400 | D | 15A | None | Rear | Rear | S-2 | 259.50 |
| C-482M | Rack | 325-525 | 0-400 | D | 15A | 3½" rect | Rear | Rear | S-2 | 289.50 |
| C-880 | Rack | 0-280 | 0-800 | E | 20A | None | Rear | Rear | S-3 | 340.00 |
| C-880M | Rack | 0-280 | 0-800 | E | 20A | 3½" rect | Rear | Rear | S-3 | 370.00 |
| C-881 | Rack | 125-325 | 0-800 | E | 20A | None | Rear | Rear | S-3 | 315.00 |
| C-881M | Rack | 125-325 | 0-800 | E | 20A | 3½" rect | Rear | Rear | S-3 | 345.00 |
| C-882 | Rack | 325 525 | 0-800 | E | 20A | None | Rear | Rear | S-3 | 360.00 |
| C-882M | Rack | 325-525 | 0-800 | E | 20A | 3½" rect | Rear | Rear | S-3 | 390.00 |
| C-1580 | Rack | 0-280 | 0-1500 | F | 30A | None | Rear | Rear | S-4 | 550.00 |
| C-1580M | Rack | 0-280 | 0-1500 | F | 30A | 3½" rect | Rear | Rear | S-4 | 580.00 |
| C-1581 | Rack | 125-325 | 0-1500 | F | 30A | None | Rear | Rear | S-4 | 575.00 |
| C-1581M | Rack | 125-325 | 0-1500 | F | 30A | 3½" rect | Rear | Rear | S-4 | 605.00 |
| C-1582 | Rack | 325-525 | 0-1500 | F | 30A | None | Rear | Rear | S-4 | 650.00 |
| C-1582M | Rack | 325-525 | 0-1500 | F | 30A | 3½" rect | Rear | Rear | S-4 | 680.00 |
| 28 | Rack | 200-325 | 0-100 | G | 3A | None | Rear | Rear | S-5 | 90.50 |
| 28M | Rack | 200-325 | 0-100 | G | 3A | 3½" rect | Rear | Rear | S-5 | 99.50 |
| 29 | Rack | 100-200 | 0-100 | H | 3A | None | Rear | Rear | S-5 | 90.50 |
| 29M | Rack | 100-200 | 0-100 | H | 3A | 3½" rect | Rear | Rear | S-5 | 99.50 |
| 32 | Rack | 200-325 | 0-300 | J | 2 @ 5A | None | Rear | Rear | S-6 | 139.50 |
| 32M | Rack | 200-325 | 0-300 | J | 2 @ 5A | 3½" rect | Rear | Rear | S-6 | 169.50 |
| 33 | Rack | 100-200 | 0-300 | J | 2 @ 5A | None | Rear | Rear | S-6 | 154.50 |
| 33M | Rack | 100-200 | 0-300 | J | 2 @ 5A | 3½" rect | Rear | Rear | S-6 | 184.50 |
| 50R | Rack | 0-500 | 0-500 | K | 2 @ 5A | 4½" rect | Front | Fr & rear | S-7 | 420.00 |
| | | 0-50 | Bias | L | | | | | | |
| | | 0-280 | High Imped. | M | | | | | | |
| **REGULATED POWER SUPPLIES—PORTABLE AND BENCH** | | | | | | | | | | |
| 25 | Bench | 200-325 | 0-100 | G | 3A | None | Front | Front | S-8 | 80.50 |
| 26 | Bench | 100-200 | 0-100 | H | 3A | None | Front | Front | S-8 | 79.50 |
| 50 | Bench | | | | | See Model 50R above | | | S-9 | 440.00 |
| 71 | Portable | 0-500 | 0-200 | N | 2 @ 5A | 3½" rect | Front | Front | S-10 | 310.00 |
| | | 0-50 | Bias | P | | | | | | |
| | | 0-200 | High Imped. | Q | | | | | | |

**TABLE I**

**DC OUTPUT VOLTAGE REGULATION, IMPEDANCE, RIPPLE**

| | Regulation: Line (105-125 VAC) | Regulation: Load (min to max) | Internal Impedance (ohms) | Ripple, rms (millivolts or %) |
|---|---|---|---|---|
| | Less than | Less than | Less than | Less than |
| A | 0.15% or 20MV | 0.15% or 20MV | 0.50 | 1 mv |
| B | 0.15% or 20MV | 0.15% or 20MV | 0.025 | 1 mv |
| C | 0.15% or 0.3V | 0.25% or 0.5V | 6 | 3 mv |
| D | 0.15% or 0.3V | 0.25% or 0.5V | 3 | 3 mv |
| E | 0.15% or 0.3V | 0.25% or 0.5V | 1.5 | 3 mv |
| F | 0.15% or 0.3V | 0.25% or 0.5V | 0.75 | 3 mv |
| G | 1% | 1% | 10 | 10 mv |
| H | 1% | 1% | 10 | 5 mv |
| J | 1% | 1% | 4 | 10 mv |
| K | 0.15% or 0.1V | 0.5% or 0.3V | 2 | 5 mv |
| L | 0.1% | unregulated | 3,500 | 2 mv |
| M | 0.1% | unregulated | 17,500 | 5 mv |
| N | 0.15% or 0.3V | 0.15% or 0.3V | 4 | 5 mv |
| P | 0.1% | unregulated | 8,500 | 2 mv |
| Q | 0.1% | unregulated | 25,000 | 5 mv |

**TABLE II**

**SIZES AND WEIGHTS**

| | Size H x W x D (inches) | Weight: Net (lbs) | Weight: Shipping (lbs) |
|---|---|---|---|
| S-1 | 3½ x 19 x 14½ | 25 | 65 |
| S-2 | 5¼ x 19 x 14½ | 53 | 80 |
| S-3 | 7 x 19 x 14½ | 84 | 100 |
| S-4 | 8¾ x 19 x 14½ | 120 | 140 |
| S-5 | 5¼ x 19 x 8 | 10 | 23 |
| S-6 | 10½ x 19 x 8¼ | 42 | 92 |
| S-7 | 10½ x 19 x 14½ | 80 | 140 |
| S-8 | 8 x 14 x 8 | 10 | 23 |
| S-9 | 12½ x 22 x 15 | 110 | 156 |
| S-10 | 13 x 8¾ x 14½ | 40 | 65 |

### GENERAL SPECIFICATIONS

Sufficient tolerance is incorporated in the specifications to allow for normal commercial component and tube deviations. Tube replacements may be made with any equivalent tubes meeting E.I.A. specifications.

**INPUT** 105-125 VAC, 50-400 CPS, single phase. Exceptions: Models 50, 50R and 71 — 105-125 VAC, 50-60 CPS.

**DC OUTPUT** *Voltage Range:* Continuously variable over ranges specified, except where otherwise noted.

*Current Range:* The current ranges given apply to the entire DC output voltage range, and for input voltages from 105 to 125 VAC. No "de-rating" is necessary.

*Polarity:* Either positive or negative terminal may be grounded.

**AC OUTPUT** The AC output is unregulated, isolated and ungrounded. It has a value of slightly higher than 6.3 V (when fully loaded) at an input of 115 VAC. This value allows for voltage drop in connecting leads. Dual outputs may be connected in series or parallel.

**DUTY CYCLE** Continuous duty at full load.

**METERS** Where meters are indicated, a separate voltmeter and milliammeter are provided.

**OVERLOAD PROTECTION** Ample protection is provided against external overload and internal failure conditions by means of fuses.

Circuit breakers of the magnetic, "trip-free" type are employed in Models 50, 50R, 71 and LT series as protection against external overloads. And in the LT series, the transistor complement is independently protected by special transistor circuitry.

**STYLE** Rack Models are designed for mounting on standard 19" relay racks.

Bench Models are provided with compact, specially-designed, ventilated cabinets equipped with carrying handles. The power supply units may be removed from their cabinets for mounting in standard relay racks (except Models 25, 26 and 71).

**RATINGS AND COMPONENTS** All components used are of the highest quality and are operated well within manufacturers' ratings. Hermetically-sealed, oil-filled capacitors are used exclusively, except in LT series, where special high purity foil, long-life electrolytics are used. "C" and "LT" series power supplies use hermetically-sealed magnetic components exclusively. Ample safety factors are provided in the design to insure the long life, and the dependable, trouble-free operation so desirable in industrial and laboratory applications.

*All specifications and prices subject to change without notice.*


**LAMBDA ELECTRONICS CORP.**

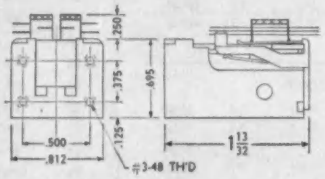
11-11 131 STREET • COLLEGE POINT 56, NEW YORK

INDEPENDENCE 1-8500 CABLE ADDRESS: LAMBDATRON, NEW YORK


*Keep this check list handy*

# new sensitive miniature relay

**TYPE TQA** is a sturdy, very sensitive, miniature relay, for D.C. operation at sensitivities from 20 to 100 milliwatts. Where shock and vibration are negligible, sensitivity of 15 milliwatts per pole is available. Contact assemblies forms A, B or C, up to a total of 18 springs. CONTACT RATING with resistive load at 28 VDC, or 115 VAC: silver contacts, 3 amperes; palladium or gold alloy, 0.5 amperes. CONTACT LIFE: 100,000 operations, minimum. OPERATING TEMPERATURE: —55°C to +100°C. Also available, —65°C to +125°C on special order. SHOCK: Up to 50G. VIBRATION: Up to 10G, from 10 to 500 CPS. Available in hermetically sealed enclosures as Type TQAH.




| | TYPE TQA SPDT | | TYPE TQA DPDT | |
|---|---|---|---|---|
| COIL RESIST. OHMS | OPERATE MA. DC | RELEASE MA. DC | OPERATE MA. DC | RELEASE MA. DC |
| 50 | 20 | 7.0 | 28 | 10 |
| 100 | 14 | 5.0 | 20 | 7.0 |
| 200 | 10 | 3.5 | 14 | 5.0 |
| 500 | 6.3 | 2.3 | 9.0 | 3.1 |
| 1,000 | 4.5 | 1.5 | 6.3 | 2.3 |
| 2,500 | 2.8 | 1.0 | 4.0 | 1.4 |
| 5,000 | 2.0 | 0.7 | 2.8 | 1.0 |
| 8,000 | 1.6 | 0.50 | 2.3 | 0.8 |
| 12,000 | 1.3 | 0.40 | 1.8 | 0.6 |

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ELECTRIC COMPANY
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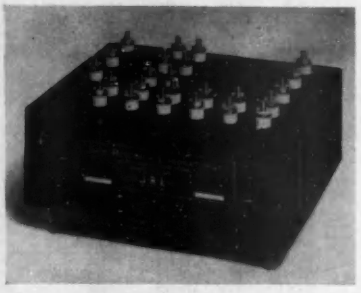
RELAYS • SOLENOIDS • COILS • SWITCHES • HERMETIC SEALING

CIRCLE 101 ON READER-SERVICE CARD




also the first to incorporate the new high-resolution Golay or capillary columns. These features enable it to pick up components at a level of approximately $10^{-9}$ grams without difficulty. At 160 deg F, it will separate hydrocarbon components from $C_8$ to $C_{12}$ in a reasonably short time. Neither helium gas nor a balanced reference are required. Wound in the form of a spool, the Golay column provides a resolution of up to 200,000 theoretical plates with a 200-ft column. Housing measures 30 in. long by 12 in. deep by 10 in. high.—Perkin-Elmer Corp., Norwalk, Conn.

**Circle No. 212 on reply card**



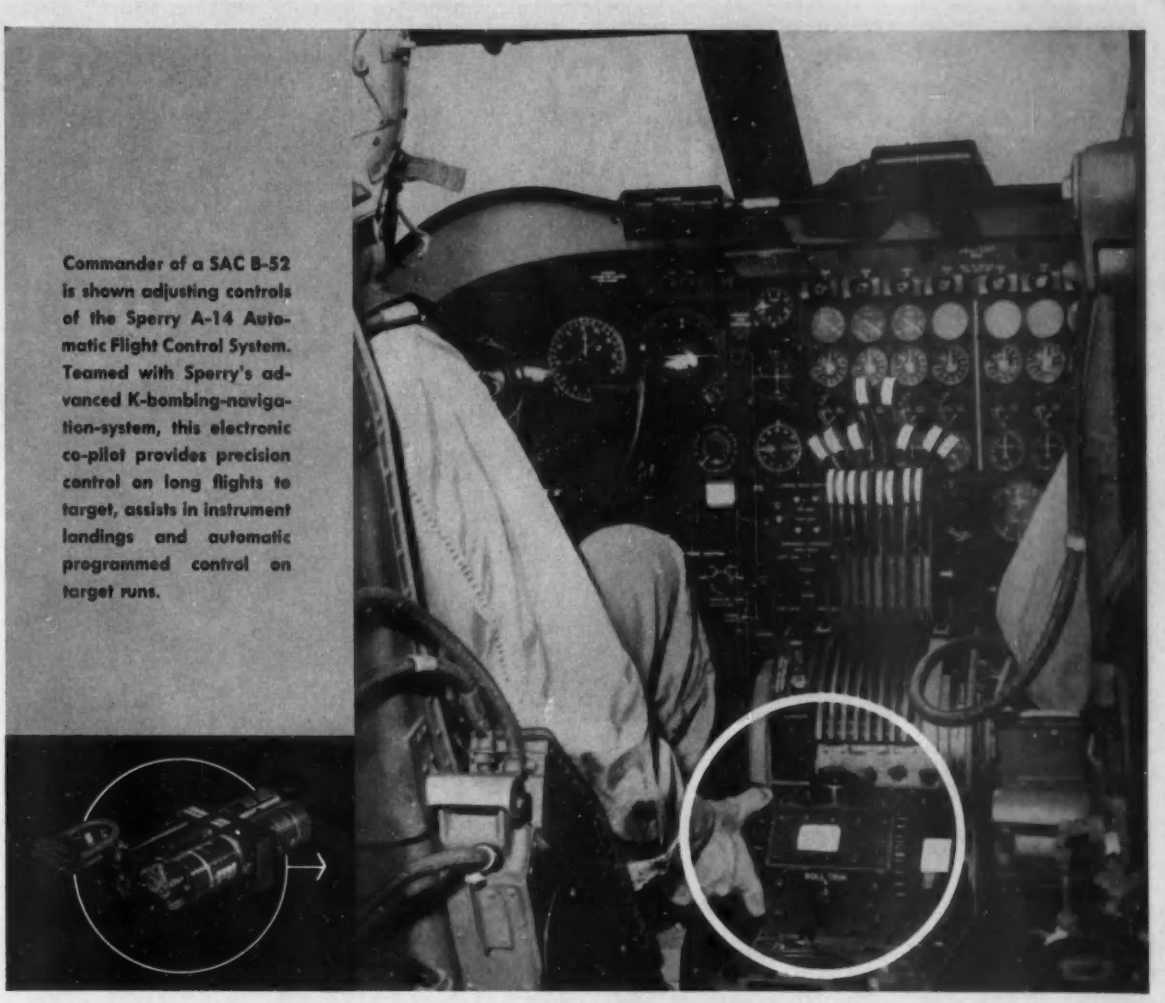
## ULTRA-PRECISE

High-precision digital-to-analog conversion, analog resistance synthesis, and laboratory calibration are typical of the applications for which this extremely accurate resistance set is suited. Called the Model BMR-105, it consists of 17 precision resistors, with values coded in binary sequence; it is suspended in an oil bath and hermetically sealed. With all resistors series-connected, accuracy is within 15 parts per million.—Julie Research Laboratories, Inc., New York, N. Y.

**Circle No. 213 on reply card**

## FOR LABORATORY USE

Design of the Model B821 Low Impedance Comparator is based on a three-terminal transformer ratio-arm bridge circuit. This gives a high degree of stability and discrimination. The instrument compares impedances in the order of 1,000 ohms against a known standard with an error of only 0.001 percent, and covers ratios between standard and unknown of from 0.8:1 to 1.2:1 in steps of 0.00001. An external audio-frequency source and detector are required. Maximum ef-



Commander of a SAC B-52 is shown adjusting controls of the Sperry A-14 Automatic Flight Control System. Teamed with Sperry's advanced K-bombing-navigation-system, this electronic co-pilot provides precision control on long flights to target, assists in instrument landings and automatic programmed control on target runs.

# servo assist for sperry's electronic co-pilot

When the commander of a B-52 gives his Stratofortress the order to execute this or that maneuver, the control system of his "electronic co-pilot" automatically applies just the right force on the control surfaces to obtain the desired maneuver under the prevailing flight conditions. That's automatic flight control at its finest!

Daystrom Transicoil helps provide the calculated muscle for this flight system in the form of servo controlled pitch, roll, and yaw follow up; coordination integrator; and pitch integrator. Only the highest level of accuracy, performance, and reliability will do . . . for you, for us.

The engineering and manufacturing assistance you need to turn modern system requirements into optimized working sub-systems and assemblies is the very basis of our business. Contact us direct or through our local representative. Check into our 24 Hour Service on servo motors and generators. Daystrom Transicoil, Division of Daystrom, Inc., Worcester, Montgomery County, Pennsylvania. (Phone: JUNO 4-2421)

**DAYSTROM TRANSICOIL** DIVISION OF DAYSTROM, INC.

*Representatives in Canada and Other Foreign Countries*

CIRCLE 102 ON READER-SERVICE CARD

# Compact! Easy to Read! Union Data Display Indicators

**Union Switch & Signal** makes two types of electro-mechanical, DC-operated data display indicators: digital types, displaying 10, 12, or 16 characters on a wheel; and alpha-numerical types, displaying up to 64 characters on a MYLAR* belt. Character assignments can be furnished as required.

**TRANSLATION** Both Digital and Alpha-Numerical Indicators operate directly on binary codes on a null-seeking basis. This eliminates the need for external equipment for translation from binary to decimal code, as required with other display devices.

**VISUAL READ-OUT** Indicator packages are designed for quick, easy readability, even when indicators are mounted in rows.

**INFINITE RETENTIVITY** The indicators require power only during the response time, because they are of the null-seeking type. Once positioned, the indicators *retain* the data visually and electrically until a new code is transmitted.

**ELECTRICAL READ-OUT** The design of the decoding and control portions of the indicators provides electrical read-out of data in the same form as the input. The data can be read continuously or periodically without erasing the stored information.

**USES** These indicators can be used in the output of digital computers, in teletype receiving equipment, in telemetering systems, or wherever data needs to be displayed. Bulletin No. 1015 gives you complete information.

*Dupont's synthetic fiber.

*"Pioneers in Push-Button Science"*

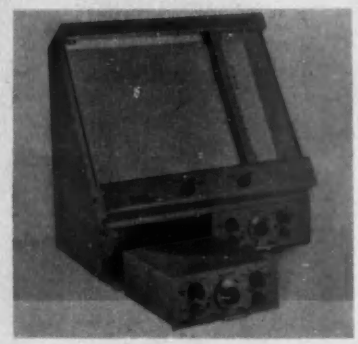
UNION SWITCH & SIGNAL
DIVISION OF WESTINGHOUSE AIR BRAKE COMPANY
PITTSBURGH 18, PENNSYLVANIA

CIRCLE 103 ON READER-SERVICE CARD



fective impedance, looking back into the bridge, is a few milliohms; measurement frequency can be from 500 cps to 5 kc.—Wayne Kerr Corp., Philadelphia, Pa.

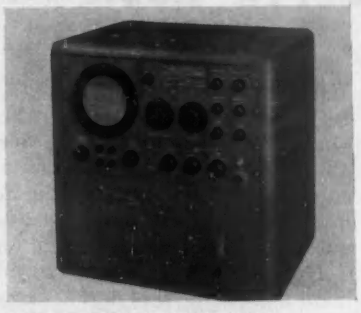
Circle No. **214** on reply card



### MODULAR INPUTS

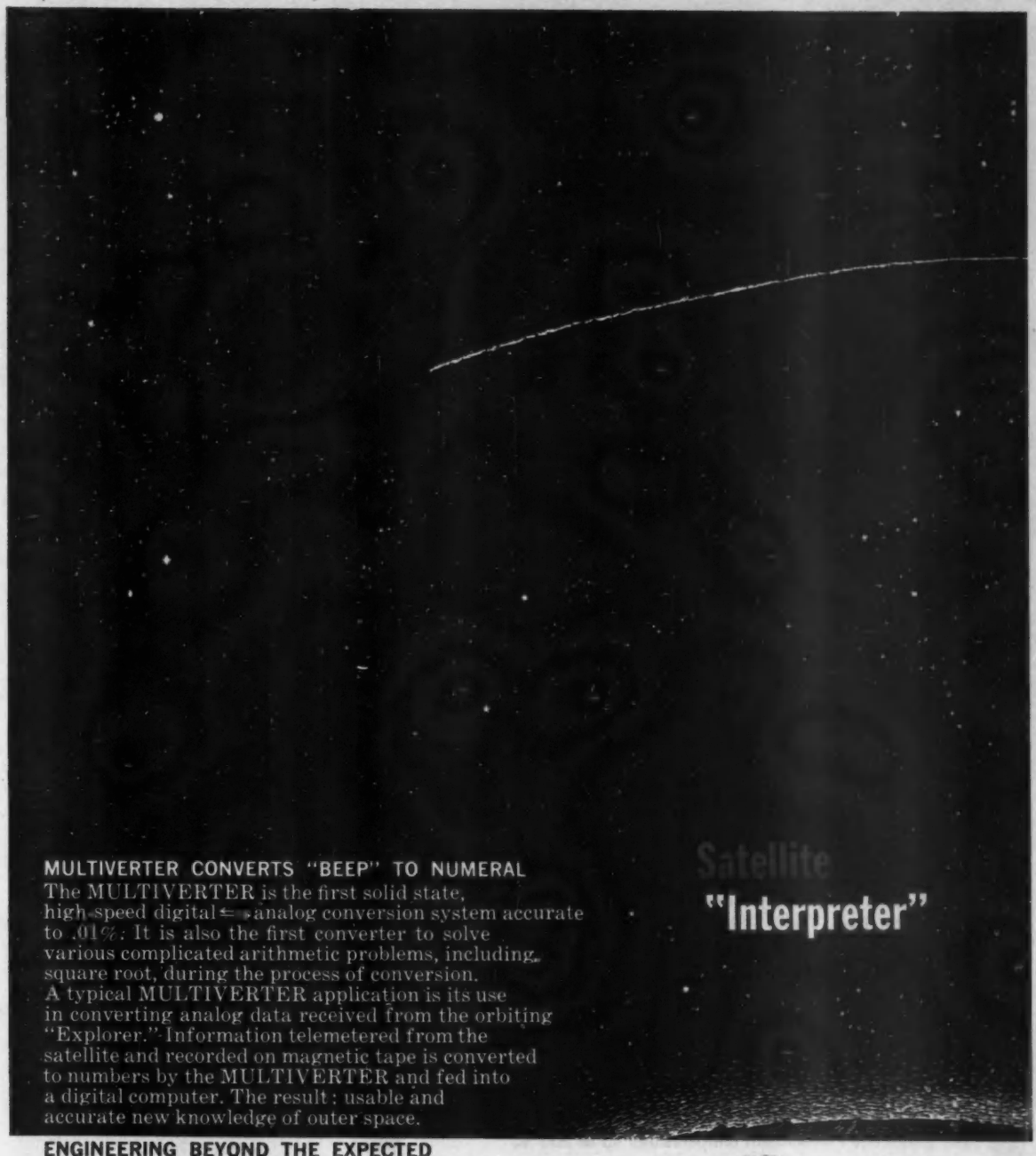
A new line of fully transistorized 11 by 17 in. X-Y recorders embodies a brand-new design concept. The unit consists of a basic plotter with separate input modules for general-purpose-computer, low-level-differential, time-base, curve-following, and other specialized functions. Improvements over earlier models include faster slewing speeds, greater accuracies, 10-microvolt sensitivity, front-panel gain control, and calibrated scales on both axes.—Electro Instruments, San Diego, Calif.

Circle No. **215** on reply card



### SPECTRUM ANALYZERS

High-sensitivity, high-resolution, and wide-frequency ranges are featured in two new spectrum analyzers, the Models SPA-3 and SPA-3/25. Design of the units permits analysis of pulse spectra, noise, line spectra, and other complex ultrasonic and low rf waveforms. Frequency ranges are from 200 cps to 15 megacycles and from

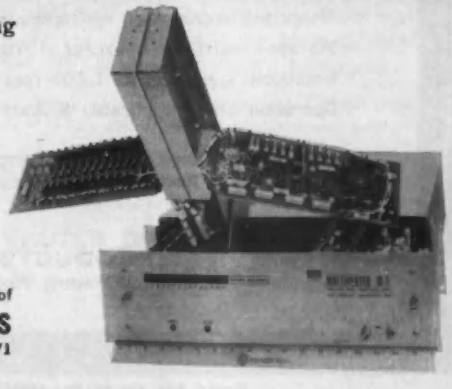



**MULTIVERTER CONVERTS "BEEP" TO NUMERAL**

The MULTIVERTER is the first solid state, high-speed digital ⇄ analog conversion system accurate to .01%. It is also the first converter to solve various complicated arithmetic problems, including square root, during the process of conversion. A typical MULTIVERTER application is its use in converting analog data received from the orbiting "Explorer." Information telemetered from the satellite and recorded on magnetic tape is converted to numbers by the MULTIVERTER and fed into a digital computer. The result: usable and accurate new knowledge of outer space.

**ENGINEERING BEYOND THE EXPECTED**

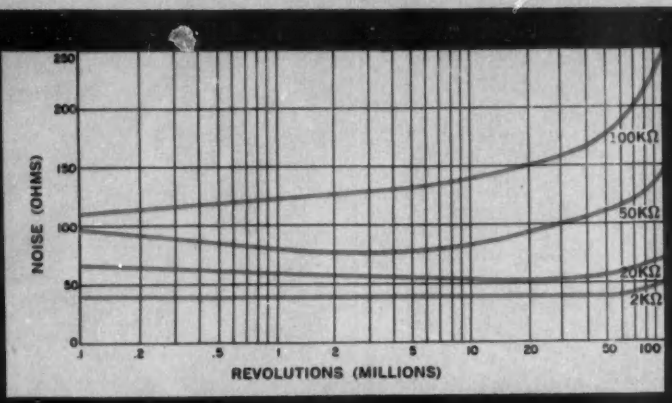
**The need for highly accurate measurement in an accelerating technology called for a solid state converter with an accuracy of .01% and a speed of four microseconds per bit. The MULTIVERTER and related accessories resulted. One immediate application has been the interconnection of Packard Bell's TRICE, the first incremental differential analyzer to operate in real time, with various analog systems. Other applications include Missile Impact Prediction, Coordinate Conversion, Orbit Prediction and Solid State Automatic Checkout Systems.**



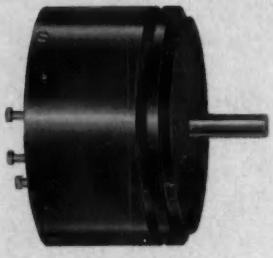
Packard Bell Computer Corp., a subsidiary of

**PACKARD BELL ELECTRONICS**

12333 W. Olympic Blvd., Los Angeles 64, Calif., BR 2-2171




# 50 MILLION
## REVOLUTIONS



The capability of maintaining low noise operation for millions of cycles is inherent in the design of Markite Conductive Plastic Potentiometers. The noise curves above are typical of the reliability and performance that can be expected of all Markite potentiometers.

**In addition to reliable and predictable performance, Markite Conductive Plastic Potentiometers also provide:**

- **Infinite resolution.**
- **Independent linearity to 0.05% in 1 5/16 inch dia. units.**
- **Operation in ambient temperatures up to 200°C.**
- **Shock and acceleration resistance in excess of 100g.**
- **Vibration resistance in excess of 70g.**
- **Rotational speeds up to 1,000 rpm and beyond.**
- **Operation under applicable Military Specifications.**

**Write for Design Data and Catalog for Rotary and Rectilinear Potentiometers**

MARKITE **PRODUCTS CORPORATION**
**155 Waverly Place • New York 14, N. Y.**

**CIRCLE 105 ON READER-SERVICE CARD**


## NEW PRODUCTS

200 cps to 25 megacycles. Other features include a continuously variable scanning width, a variable center frequency control, variable resolution, and a variable sweep rate.–Panoramic Radio Products, Inc., Mount Vernon, N. Y.

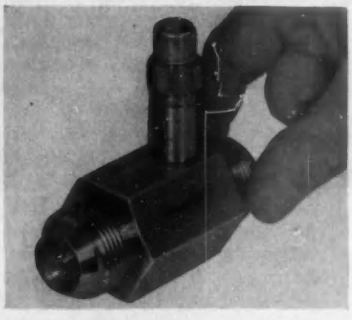
**Circle No. 216 on reply card**

PLUS . . .

(217) A new multichannel pulse-bright **analyzer,** Model 4100, is now available from **Eldorado Electronics,** Berkeley, Calif. . . . (218) **Microsound, Inc.,** Culver City, Calif., offers a new **recording-projecting oscilloscope,** the Datascope, which can store and project transient phenomena from dc to 5,000 cps. . . . (219) The Model MV-77A **DC Multimeter,** by **Millivac Instruments Div. of Cohu Electronics, Inc.,** Schenectady, N. Y., combines sensitive measurement of millivolts and microamperes with an accurate, linear-scale ohmeter. . . . (220) The **Victoreen Instrument Co.,** Cleveland, announces availability of three new **vacuum-tube electrometers** for measuring currents as low as $2 \times 10^{-13}$ amp.

**Circle No. 217, 218, 219, or 220 on reply card**

## PRIMARY ELEMENTS & TRANSDUCERS

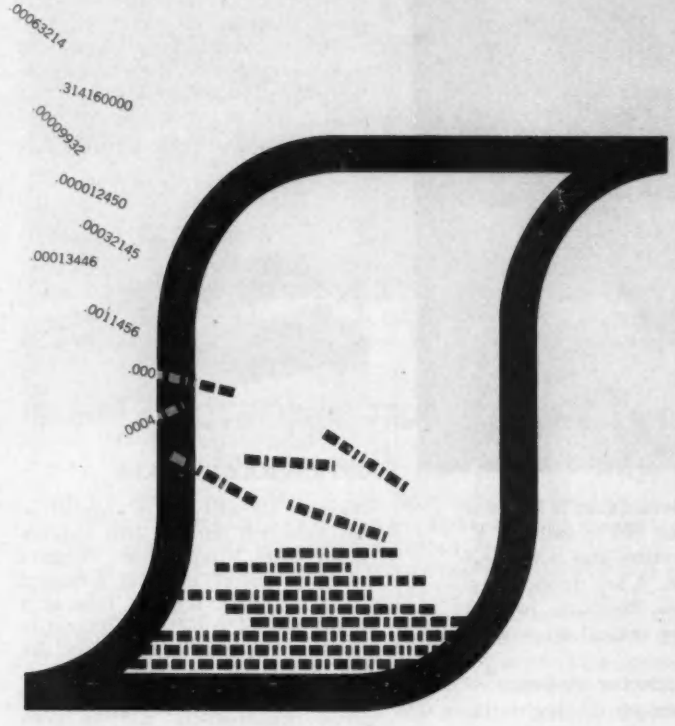


### LOW HEAD LOSS

A new line of completely redesigned turbine-type flowmeters, called the Type 20, features accuracies within 0.5 percent at pressures up to 5,000 psi and temperatures between minus 455 and 1,000 deg F. Suitable for handling jet fuels, gasoline, oil, water, and liquid chemicals, the new meters boast a permanent pressure loss of

## TAPING CRITICAL INFORMATION?

*"SCOTCH" Brand high potency oxides let you pack more bits per inch!*

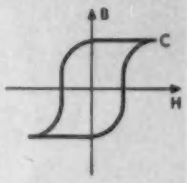



Every day SCOTCH Brand High Resolution Tapes are getting the nod for more instrumentation jobs. The reason? Performance. In taping high frequency data, the sharper resolution lets you pack more pulses to the inch—a greater density of information to each foot of tape.

At the root of this advance are the high potency oxides used in the magnetic coating. The higher magnetic retentivity of these oxides—about a third more than standard—offers distinct advantages. It permits the use of a thinner magnetic coating which may be combined with a thinner polyester base. Naturally, this means a more flexible tape — one that conforms for more intimate tape-to-head contact, automatically improving resolution in the taping of high frequencies.

Even so, you don't have to sacrifice output in low frequencies. For in addition to the marked increase in sensitivity to short wave lengths, SCOTCH Brand High Resolution Tapes show some increase in sensitivity even to long wave lengths.

These more flexible tapes cut drop-outs, too. With better tape-to-head contact, there's less chance that a stray bit of dust can sneak between tape and head to cause a drop-out. The superior magnetic properties of SCOTCH Brand High Resolution Tape No. 159 show up in oscilloscope tests—producing a good squared-up hysteresis curve like that shown at the right, and symbolically illustrated at the left.




Whatever your application—data acquisition, reduction or control programming—you can count on SCOTCH Brand technology to create tapes of higher uniformity and reliability for error-free performance.

SCOTCH Brand High Output Tape No. 128 provides the sensitivity for good output in low frequencies, even under extremes of ambient temperature. SCOTCH Brand Sandwich Tapes No. 188 and 189 offer extremely long life and reduced head wear in digital work and many AM, FM and PDM applications. Finally, for top performance at low cost per foot, SCOTCH Brand Instrumentation Tapes No. 108 and 109 remain the standard for the industry.

Where there's no margin for error, there's no tape like SCOTCH Brand. For more details, mail the reader inquiry card or write Magnetic Products Div., 3M Company, St. Paul 6, Minnesota.

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**SCOTCH BRAND MAGNETIC TAPE**

FOR INSTRUMENTATION

MINNESOTA MINING AND MANUFACTURING COMPANY

... WHERE RESEARCH IS THE KEY TO TOMORROW

3M COMPANY

# NEW WESTINGHOUSE LIMITEMP
## Indicating Temperature Control

Limitemp* is a new, medium-priced control device that is ideal for monitoring or controlling temperatures between 100° F and 400° F. Controller may be used to indicate temperature and sound an alarm if temperature exceeds the preset point. A few applications include windings of large rotating machines, bearings, process temperatures and controlling temperatures in critical areas such as nuclear controls.

Limitemp employs magnetic and semiconductor elements of proven reliability; therefore, no vacuum tubes, no moving parts, no contacts . . . nothing to wear out.

**LIMITEMP CHARACTERISTICS:**
INPUT: 115 volts, 60 cycles OUTPUT: 24 volts d-c at 5 watts
TEMPERATURE RANGE: 100° F to 400° F—40° C to 200° C
INDICATION: Dual-scale calibrated meter and pilot light
ACCURACY: Setting ±1%, indicating ±2%, bandwidth 2% of range
COMPACT: 4 in. wide, 8½ in. high, 6 in. deep

**GET ALL THE FACTS . . .** write Westinghouse Electric Corporation, Director Systems Dept., 356 Collins Avenue, Pittsburgh 6, Pa. Complete information on the new Westinghouse Limitemp will be sent to you by return mail. J-01008

*Trade-Mark

YOU CAN BE SURE...IF IT'S Westinghouse

WATCH "WESTINGHOUSE LUCILLE BALL-DESI ARNAZ SHOWS" CBS TV MONDAYS

CIRCLE 107 ON READER-SERVICE CARD



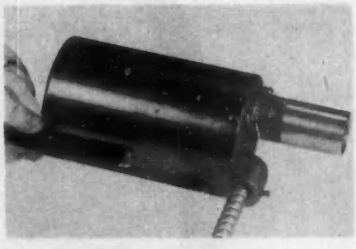

only 5 psi at maximum rated flow under normal conditions. Linear flow ranges with maximum/minimum flow ratios of 35:1 are available. Low rotor inertia provides a transient response time of only 3 msec.—George L. Nankervis Co., Detroit, Mich.

**Circle No. 221 on reply card**

### HIGH-OUTPUT LVDT'S

A series of high-output linear variable differential transformers features a full-displacement output of 45 mw for a 115-volt, 60-cycle excitation. In many applications, this low frequency eliminates the need for a signal generator. Units also feature a low "zero phase" frequency, a characteristic that minimizes changes in sensitivity due to temperature and frequency variations.—Schaevitz Engineering, Pennsauken, N. J.

**Circle No. 222 on reply card**



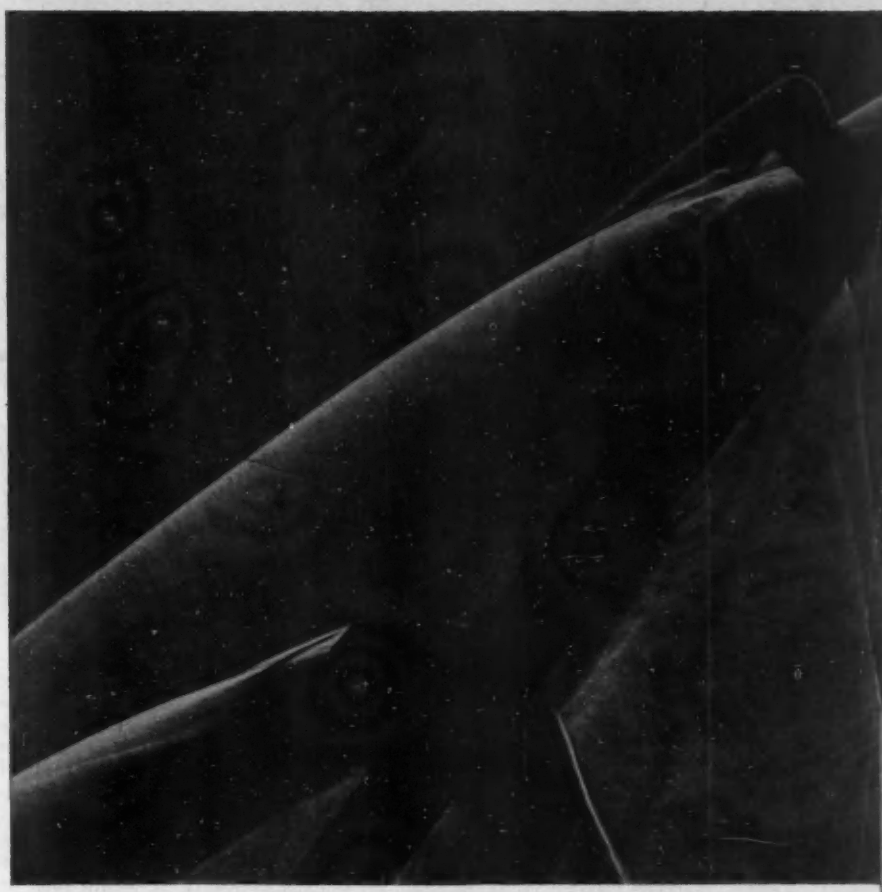
### ULTRAVIOLET PICKUP

Designed for all types of commercial and industrial burners, this self-contained Ultra Vision Flame Detector integrates energy impulses generated by an ultraviolet sensitive tube as it counts the ultraviolet rays present in the flame. Company claims the system, which uses an amplifier circuit, may be used with all fuels, including gas-oil combinations, and on both single and multiple burners. System sells for $120.—Minneapolis-Honeywell Regulator Co., Minneapolis, Minn.

**Circle No. 223 on reply card**

### SHOCK-RESISTANT

Converter-transducers that convert an ac input into a dc output have been developed for measuring, telemetering, and control applications. Units replace potentiometers where ac is available. Advantages include infinite resolution, high linearity and sensitiv-



In the wind tunnel of the Naval Supersonic Laboratory at M.I.T., a missile model is subjected to speeds of several Mach numbers. B-L-H SR-4 bonded wire strain gages report longitudinal and latitudinal stresses, drag, lift, etc., with high accuracy.

## *B-L-H ELECTRONIC TRANSDUCERS measure forces with new ease and accuracy*

With the arrival of the Space Age have come increasingly severe demands on measuring instrumentation for precision and versatility. Accurate center of gravity computations, for example, are now more than important—they are vital.

B-L-H SR-4® transducers are highly responsive, durable and adaptable. Stock units offer long-term accuracy of ±1/10% and repeatability of ±1/20%. They will measure any forces involving tension or compression, torque, etc. With appropriate instrumentation, they can also determine center of gravity, weigh loads at rest or in motion, control batch and continuous processes, and record all data required. The type and number of applications are virtually unlimited.

The heart of every B-L-H transducer is its SR-4 bonded wire strain gages. They are bonded to a metal element in the transducer and approximately 10 milliamperes is fed through them. They receive the same strains as the transducer when a force is applied. Their electrical resistance changes in linear relationship with strain. The voltage output can be calibrated directly in terms of load—or fed into any common types of instrumentation, such as dial indicators, graphic recorders, digital printers, computers, etc.

For more information on SR-4 electronic transducers—load cells, pressure cells, or torque meters—ask to have a B-L-H man call on you—or write on your company letterhead for a copy of "Modern Force Measurement." Address Dept. 6-E.

(top to bottom) Load cell, pressure cell, and torque meter transducers.

**BALDWIN · LIMA · HAMILTON**

Electronics & Instrumentation Division

Waltham, Mass.

SR-4® strain gages • Transducers • Testing machines

Copyright 1958, E&I Div., B-L-H Corp.

interchangeable with all standard JIC cylinders

**With the introduction of the ALL NEW T-J Squair Head, Tomkins-Johnson now offers industry the most complete design range of air and hydraulic cylinders. Presently available in bore diameters from 1-½ to 8 inches, the T-J Squair Head is an interchangeable cylinder which produces maximum force and efficiency, with minimum pressures . . . and is also adaptable to the use of low pressure oil as the working medium. Write today to The Tomkins-Johnson Co., Jackson, Michigan, for Bulletin #SQ 10-58 and complete details.**

***CHECK THESE 10 POINTS OF T-J SUPERIORITY***

1. One Piece Piston
2. Hard Chrome Cylinder Bore and Piston Rods
3. High Tensile Steel Tie-Rods
4. Cushion Adjusting Screw, Externally Adjustable
5. New Super-Cushion for air, or Self-Aligning Master Seal for oil (T-J Patents)
6. Solid Steel Heads and Mounting Plates Standard all Models
7. Port Design Allows Minimum Pressure Drop on Inlet or Outlet
8. Chevron Type, Self-Adjusting Rod Packing
9. Piloted Packing Gland—Absolute Alignment
10. Piston Rod, Extra Strong—Polished and Chrome Plated for Efficiency and Protection

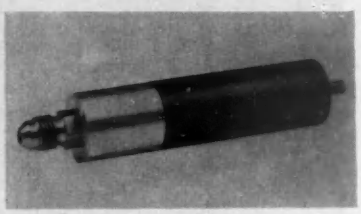
T-J TOMKINS-JOHNSON
RIVITORS . . . AIR AND HYDRAULIC CYLINDERS . . . CUTTERS . . . CLINCHORS

CIRCLE 109 ON READER-SERVICE CARD

## NEW PRODUCTS

ity, resistance to severe shock and vibration, and the absence of sliding contacts. Threshold sensitivity is said to be better than 0.0001 percent of full scale; temperature range, minus 320 to 250 deg F.—Vinson Engineering & Sales Co., Van Nuys, Calif.

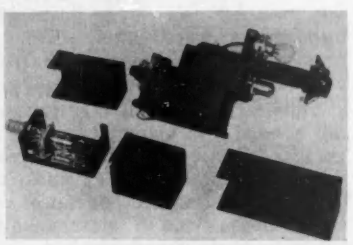
**Circle No. 224 on reply card**



### RUGGED AND STABLE

Designed for measuring a wide range of gage, absolute, or differential pressures, the Model PFS-4 pressure-to-frequency system combines in a single rugged package a specially designed reactance-controlled subcarrier oscillator and a single-coil, variable-reluctance pressure transducer. Close matching of oscillator and transducer holds nonlinearity to within plus or minus 1 percent. Since the only moving part in the system is a small, stiff diaphragm in the transducer, the package has excellent resistance to shock, vibration, and acceleration. This, plus its small size and light weight, make it ideal for airborne telemetry applications.—Ultradyne, Inc., Albuquerque, N. M.

**Circle No. 225 on reply card**



### READS DIAL MARKINGS

Photo above shows an exploded view of the Model T877 Photoelectric Scale Reader. This instrument provides electrical output signals at predetermined table-angle increments by automatically reading the marks engraved on a precision reference dial.—Sterling Precision Corp., Port Washington, N. Y.

**Circle No. 226 on reply card**

IRC

Compu-tran®

## PRESSURE TRANSMITTER

This unit was especially designed to extend the uses for a reliable pressure transmitter by lowering the cost. Hundreds in use in critical control systems for missile fuel unloading and nuclear reactors.

**Linearity:** ±0.5%
**Hysteresis:** 0.5%
**Resolution:** 0.2 to 0.4 (depending on resistance range)

- Easily adaptable to provide direct pressure indication or recording using standard electrical receivers.
- Rugged, frictionless, long life precision Potentiometer measuring element—available silicone oil filled, shock resistant to 15 G's.
- Adaptable to convert standard pneumatic process control signals (3 to 15 psi) to equivalent electrical signals for electric data handling system, alarm or long distance transmission.

## NEW ZERO-SETTING PRESSURE TRANSMITTER

**MEASURES DIFFERENTIAL AND ABSOLUTE PRESSURES**

**HIGH RELIABILITY—HIGH ACCURACY**

**EXCELLENT FOR INDUSTRIAL PROCESS APPLICATIONS AND MILITARY TESTING**

May be zero-set with a screw-driver for any environmental situation or to obtain zero output for any pre-set differential.

**Ranges:** 0-100 thru 0-5000 psi static pressure.

**High Accuracy:** ±0.25%, infinite resolution.

**High Reliability:** Frictionless magnetic pickoff.

**Input:** 110V or 6.3V AC adaptable to other voltages and frequencies.

**Output:** 10 to 100 MV to 5 volts. AC or DC. **Temperature Compensated.**

## DISPLACEMENT TRANSDUCER

The IRC Displacement Transducer offers higher sensitivity and better linearity. Especially suited to military applications. High resistance to moisture and shock. Wide range of standard and subminiature sizes with temperature ranges up to 1200°F.

No longer are weak outputs a problem in the application of Differential Transformers.

**Better Linearity:** 0.1%.

**Better Sensitivity:** 2.0MV/Volt input/mil @ 60 cycles.

Precision and complete interchangeability assured by close quality control during every step in manufacture.

**Special designs for:**
120V inputs and up to 50V outputs.
Zero Temperature coefficients.
Power outputs up to 1 watt.

# FOUND!...

## a reliable source for transducers

The word is spreading that there is a dependable source for pressure and displacement transducers—IRC Compu-Tran®. This news is especially welcome because IRC brings to the field a long, successful experience in producing precision equipment. The result is products of sensitivity, linearity, and reliability at previously unheard of savings.

If you design instruments for missile ground control equipment, missile guidance systems, wind tunnels, nuclear reactor cooling fluid controls, controls for the industrial process industries, jet engine controls, precision gaging and weighing devices or any other instruments requiring pressure or displacement transducers, you will want to check IRC Compu-Tran units. Write for one or all of the following bulletins: Pressure Transmitters, Bulletin R-1c; Zero-Setting Pressure Transmitters, Bulletin R-11; Displacement Transducers, Bulletin R-3.

IRC

International Resistance Company

**COMPUTER COMPONENTS DIVISION,** Dept. 242, 401 N. Broad St., Phila. 8, Pa.

In Canada: International Resistance Co., Ltd., Toronto, Licensee

CIRCLE 110 ON READER-SERVICE CARD

*easily installed*

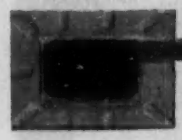
*factory calibrated*

**TRANS-SONICS**

REG. T.M.

**SURFACE TEMPERATURE TRANSDUCERS**

actual size



CEMENT-ON*, Type 1375

The temperature sensing element is encased by a die-formed wire screen which can be installed on any surface with TRANS-SONICS Type 64C cement.

| TYPE | TEMPERATURE RANGE |
|---|---|
| 1375A | −300 to +650F. |
| 1375B | 0 to 1000F. |
| 1375C | +200 to 1250F. |
| 1375D | +500 to 1550F. |

actual size

WELD-ON*, Type 1376

The temperature sensing element is encased in a thin die-formed metal cover, and is installed by spot welding the cover to the underlying metallic surface.

| TYPE | TEMPERATURE RANGE |
|---|---|
| 1376A | −300 to +650F. |
| 1376B | 0 to 1000F. |
| 1376C | +200 to 1250F. |
| 1376D | +500 to 1550F. |

- RANGES: From −400F to +1550F.
- OUTPUT: Up to 5 volts without amplification.
- RESISTANCE CHANGE: 100 ohms over calibrated range.
- ACCURACY OF CALIBRATION: ±1% of range interval ±2% for temperatures over 1000F.
- MAXIMUM CONTINUOUS CURRENT: 20 milliamperes rms.
- REPEATABILITY: ±0.2% of range interval.
- VIBRATION: 1-inch double amplitude, 0-22 cps; 25g, 22-2000 cps.
- ACCELERATION & SHOCK: 100g on all three major axes.
- LEADS: Two 6" nickel wires with high temperature insulation.

Trans-Sonics Cement-On Type 1375 and Weld-On Type 1376 Surface Temperature Transducers are platinum resistance thermometers that can be installed on any surface, flat or curved, metallic or non-metallic, for accurate temperature measurement. The protective cover of the resistive element is cemented or welded directly to the thermal surface to form an isothermal system which gives a transducer reading that corresponds to the true skin temperature.

A 5 point resistance-temperature calibration certificate at 0, ¼, ½, ¾ and full scale temperature is supplied with each transducer. A strip of aluminum Thermotape* is also furnished with each unit to provide an alternate means of tape-on installation useful to 800F and under limited conditions to 1000F.

Types 1375 and 1376 are the newest members of the Trans-Sonics family of platinum resistance thermometers for measuring surface temperatures. All units are capable of delivering up to 5 volts without amplification. Write to Trans-Sonics, Inc., Dept. 11, Burlington, Mass. for Technical Bulletin on Surface Temperature Transducers.

*TRADEMARK

**TRANS-SONICS**

*Precision Transducers*

CIRCLE 111 ON READER-SERVICE CARD

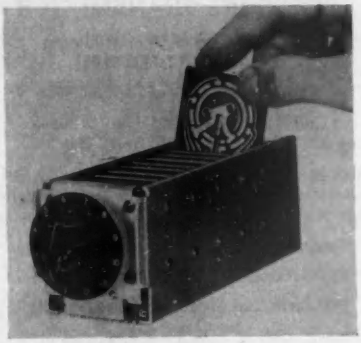

## NEW PRODUCTS

PLUS . . . .

(227) **Colvin Laboratories, Inc.**, East Orange, N. J., is now producing a Type 4417 **Pressure Transducer**, which is basically a pressure-sensing capsule that drives a precision wire-wound potentiometer. . . . (228) The Model 21 **gyro package** offered by **Sanders Associates, Inc.**, Nashua, N. H., provides a complete three-axis angular-velocity sensor for roll, pitch, and yaw indication. . . . (229) **Industrial Instruments, Inc.**, Cedar Grove, N. J., has been licensed to manufacture and sell a special high-temperature, high-pressure **conductivity cell.**

Circle **227, 228,** or **229** on reply card

## CONTROLLERS, SWITCHES, & RELAYS



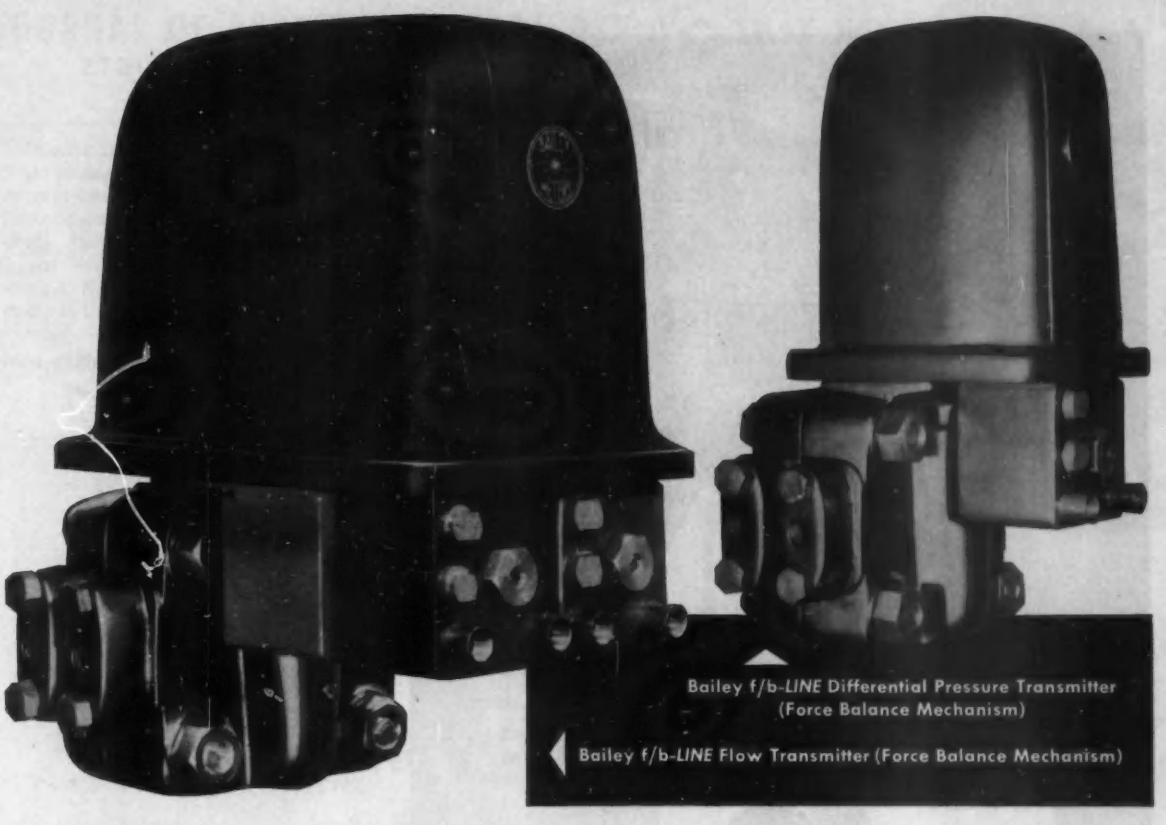
### EASY TO MAINTAIN

Photo above shows a new rotary switch in which wafer-thin elements can be removed in a matter of seconds for cleaning or replacement. No soldering or assembly time is required. Switches are available in sizes approximately 2 in. by 2 in., 3 by 3, and 4 by 4, with lengths to accommodate up to 36 wafers. Switch circuit configurations are virtually unlimited. All connections are to a single bank of receptacles at one side of the aluminum housing. Manual, motor, or solenoid operation is possible.—Chicago Dynamic Industries, Inc., Chicago, Ill.

Circle No. **230** on reply card

### PROGRAM TIMERS

Specifically designed for commercial and industrial applications, a new line of electrical programmers features



Bailey f/b-*LINE* Differential Pressure Transmitter (Force Balance Mechanism)

Bailey f/b-*LINE* Flow Transmitter (Force Balance Mechanism)

# Two new Bailey *f/b-LINE* Transmitters

## permit new accuracy in measuring flow and differential pressure

Pneumatically transmits rate of flow—or differential pressure—measurements to indicating, recording, and/or controlling equipment at remote stations. Transmitters consist of a diaphragm measuring mechanism and a force balance pneumatic transmitting unit.

### APPLICATION

For steam, water, air, gases and other fluids producing differentials across primary elements from 0-2 in. $H_2O$ to 0-2000 in. $H_2O$ at maximum service pressure of 50, 1500, and 5000 psig.

### FEATURES

**Transmits a Signal Directly Proportional to Rate of Flow.** Uses receiver with uniformly-graduated chart or scale. Eliminates need for external square-root extractors or characterizers.

**10 to 1 Turndown.** Differential range of each diaphragm measuring element may be changed by factor of 10 to 1; e.g., 0-20 in. $H_2O$ diaphragm may also measure 0-2 in. $H_2O$.

**Screwdriver Adjustments.** Range and zero adjustments readily accessible. Range may be changed with screwdriver adjustment.

**Overpressure Protection.** Protects against full service pressure applied to either side of diaphragm.

**Fast Response.** No viscous dampers needed, so speed of response is very fast.

**Corrosion Resistant.** For maximum differentials between 20 and 2000" $H_2O$, all parts in contact with process fluid may be stainless steel. No sealing fluids or sealing diaphragm required.

**Good Stability.** Reset type boosters give good stability with high gain.

**Versatile Mounting.** May be mounted on process piping, wall, or separate mounting pipe using same bracket.

For additional information, call your local Bailey District Office, or write direct. G46-1

*Instruments and controls for power and process*

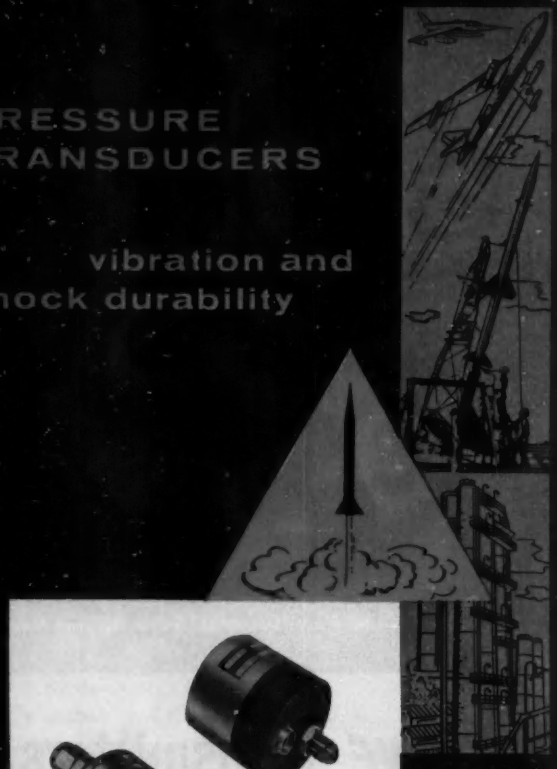
# BAILEY METER COMPANY

*1079 IVANHOE ROAD • CLEVELAND 10, OHIO*

In Canada—Bailey Meter Company Limited, Montreal

PRESSURE
TRANSDUCERS

vibration and
shock durability



missile, aircraft, and
industrial applications

*Features:*

- Vibration Durability: 10-25 g's in all axes 10 to 2000 cps
- Infinite resolution conductive plastic potentiometer with wear properties in excess of 20 million cycles
- Repeatability: 0.1 %
- Range: 0-1 to 0-300 psi

RAHM

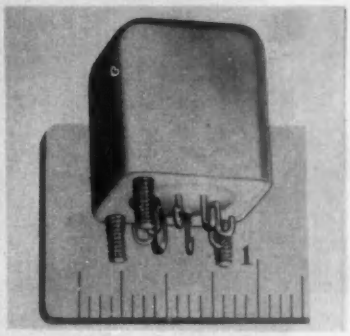
RAHM INSTRUMENTS
DIV. OF AMERICAN MACHINE AND METALS, INC.
65 Rushmore Street • Westbury, N. Y.

CIRCLE 113 ON READER-SERVICE CARD

## NEW PRODUCTS

reliability, repeatability, and adaptability. Units may have from one to eight spdt snap-action switches, and may be had with either studs or notched corners for mounting purposes. Cycling times range from 30 sec to 24 hours. Power required is only 2 watts at 115 volts, 60 cps.—A. W. Haydon Co., Waterbury, Conn.

**Circle No. 231 on reply card**



### SWITCHES HIGH CURRENTS

Rated at 5 amp for 100,000 operations (or 10 amp for 25,000 operations and 15 amp for 2,500 operations), this miniature rotary relay measures $\frac{7}{8}$ in. square by $1\frac{1}{8}$ in. deep, weighs just 1.5 oz. It features excellent vibration and shock characteristics, will operate in ambient temperature of from minus 65 to plus 125 deg C. Built for stud mounting with solder hook terminals, the unit has a dpdt contact arrangement. — Electronics Div., Elgin National Watch Co., Burbank, Calif.

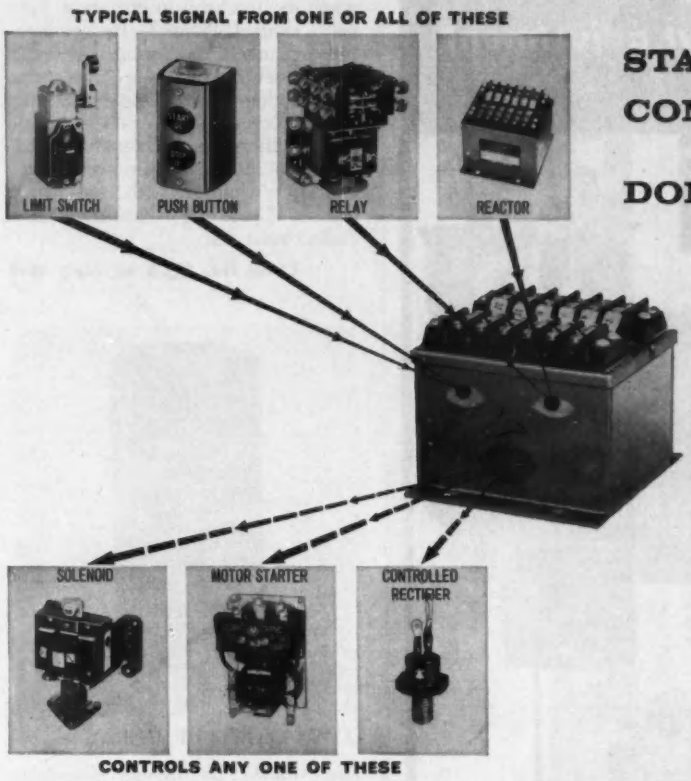
**Circle No. 232 on reply card**

### CONTROL MODULES

Compact, plug-in control units, recently introduced by L&N, feature extreme flexibility to meet the individual requirements of virtually any type of nuclear reactor. The units simplify calibration, operation, and maintenance, and permit an operator

# JOURNAL OF APPLIED CONTROL DEVICES THAT NEVER WEAR OUT

**For Control Engineers Who Are Wearing Out Before Their Time**




## STATIC CONTROL COMPLICATED?

## DON'T YOU BELIEVE IT!

An engineering friend of ours working on blast furnace controls uses a CONTROL switching reactor to take signals from a series of limit switches, temperature controllers, and relays to operate the solenoid which triggers the air blast motor. Dollars ahead he was when he saw this *selective* device would take signals from many sources, compile them, remember them, and when told to act (by the same standard input signals), leap into action. "So simple," he said—"nothing but the standard inputs we always use, switching reactor and outputs. If that's static control, I'm the new president of the C.S.R* Booster Club." *You, too, can beat the drum. Write for our catalog about Simple Static Control.*

**CONTROL Switching Reactor*

## PUSH, PULL, CLICK, CLICK *(or how to feed a switching reactor)*

Persons who hear push-pull-click-click sounds in industrial plants are not to be suspected of an affinity for the razor business. They are listening to the music of push buttons, limit switches and relays, all feeding signals into CONTROL'S switching reactors (which are engaged in static control). Our reactor is *selective*. As you dictate, it responds to control voltages which add, which oppose, or which work in combination, regardless of source. What's more, our reactor can be fed by a transducer whose output is electrical—even if it doesn't say "push, pull" or "click, click."

*If you have an affinity for money-making musical sounds, perhaps you'd like to know more about these CONTROL switching reactors. Write us.*

## CLICK, CLICK, PULL, PUSH *(or how a switching reactor feeds you)*

Here is the click-click-pull-push (output) side of the CONTROL switching reactor. Not only is it *selective* as to source and combinations of inputs, but it is a real bear for working such loads as solenoids, motor contactors and magnetic clutches. It shines, too, as a practical way of operating the new solid state thyratron from a variety of input sources. A reactor can control a single load up to 300-VA to a fare-thee-well. Loads are statically switched with nary a moving part. What's more, there is no auxiliary hardware (transformers, relays or single purpose logic units) to clutter the minds and hearts of your control engineers and purchasing agents.

*Sizes? A complete range, including 15, 75, 150, and 300 VA. There's also one especially for the solid state thyratron. Why not write for more details about our CONTROL switching reactors.*

**Reliability begins with CONTROL**

A DIVISION OF MAGNETICS, INC.

DEPT. CE-62, BUTLER, PENNSYLVANIA

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**FOR** Optimum positioning control
Minimum break-away friction
System stiffness
Long life without adjustment

ENGINEERS SPECIFY

**BEAVER** PRECISION
**BALL SCREWS**

Beaver Precision ball lead screws on all three axes provide the basic measuring and actuating elements which simplify the design of this tape controlled milling machine.

Beaver ball screws move table of this Bridgeport Mill in response to signals from the Electronic Control Systems, Inc. "Digimatic" control and are typical of those now in use on numerically controlled machine tools of all types.

If it's numerically controlled, tape or card, it is more than likely equipped with Beaver ball screws. Our engineers are available to you for consultation – can we help you improve the design of your equipment?

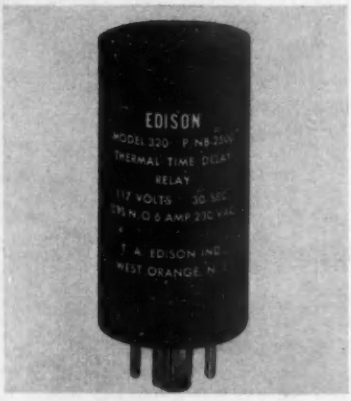
Beaver Precision Products INC.
CLAWSON, MICH.

CIRCLE 115 ON READER-SERVICE CARD


## NEW PRODUCTS

to check the system or its components while the reactor is in operation. Four basic control channels are available: pulse channels to measure the initial rise of neutron flux; log N or intermediate channels to monitor or control rate of change of flux levels up to full power; linear-servo channels to provide smooth changes in power level; and safety channels with load-sharing features–Leeds & Northrop Co., Philadelphia, Pa.

**Circle No. 233 on reply card**



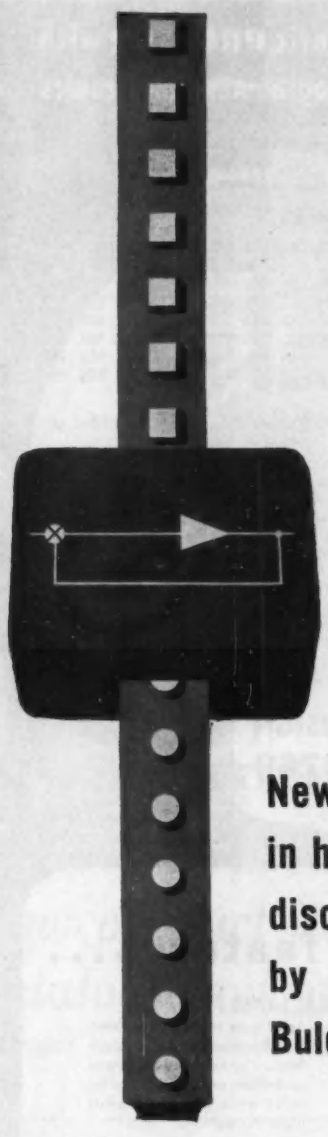

### LOW-COST TIME DELAY

The Model 320 thermal time-delay relay is a low-cost unit designed specifically to meet military requirements for ground equipment. It measures 1¾ in. in diameter by 2¼ in. long and is available with timing ranges from 15 to 120 sec. Hermetically sealed, the unit is fitted with a standard octal base.–Thomas A. Edison Industries, McGraw-Edison Co., West Orange, N. J.

**Circle No. 234 on reply card**

### PLUS . . .

(235) **a differential pressure switch,** with a unique poppet-type action, has recently been introduced by **Consolidated Controls Corp.,** Bethel, Conn. . . . (236) The Pyristor Switch, announced by **Thermocal, Inc.,** Santa Monica, Calif., is a single-shot, **current-sensitive switch** designed for circuit testing and protection, and for use in current-operated triggering devices. . . . (237) **Acoustics Associates, Inc.,** Mineola, N. Y., has developed a new ultrasonic **liquid level switch** for use in cryogenic liquids. . . . (238) **Hillburn Electronic Products Co.,** Brooklyn, N. Y., now has a **high-speed**



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**Bulova designer-engineers can help you increase production and reliability**

Turning a hand-method, high-skilled operation into a reliable mechanized facility is a proven Bulova capability.

Automating existing man-machine systems involves the creation of equipment to manufacture individual pieces and to provide continuous, automatic in-process inspection, sorting, assembly and testing. This requires techniques and methods long familiar to Bulova.

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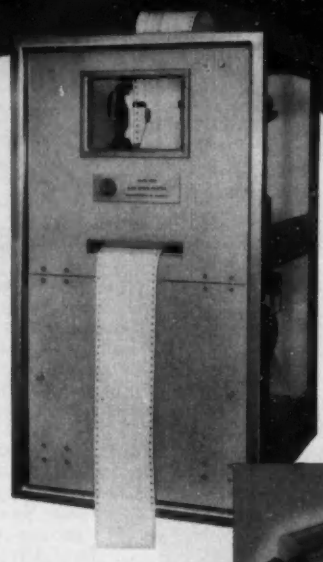

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adaptable to all digital data sources

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**OPERATING SPEEDS**
4 BIT DATA @ 20 lines/sec.
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PAPER FEED TIME.....15 Ms
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Solid state storage, transistorized hammer drive and paper feed . . . troublesome contacts and wiper arms eliminated by reluctance pickup. Digital logic throughout.

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Designs to meet MIL or Commercial Specs.

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4 or 6 bit input data in parallel or serial-parallel form and in any coding system.

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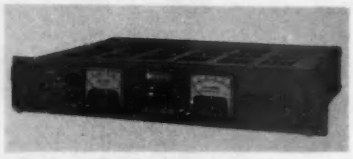
CIRCLE 117 ON READER-SERVICE CARD


## NEW PRODUCTS

**stepping relay** that will auto-home at 50 pps and follow a 25-msec square-wave pulse.

Circle No. **235**, **236**, **237**, or **238** on reply card

## POWER SUPPLIES

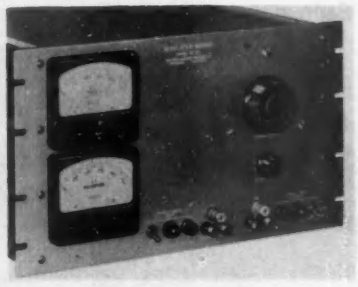


### HYBRID CIRCUIT

Photo shows one of three new voltage-regulated power supplies in which fully transistorized reference and amplification circuitry control tube-pass elements. Units delivery 200-, 400-, or 600-ma, depending on the model. Each has a dc incremental four-band output voltage range from 125 to 325 volts.

**Characteristics:**
Regulation: within 0.1 percent
Ripple: less than 3 mv rms
Recovery time: under 100 microsec
Stability (for 8 hours): within 0.1 percent
Temperature coefficient: 0.05 percent per deg C
—Kepco Laboratories, Inc., Flushing, N. Y.

Circle No. **239** on reply card



### LAB SUPPLY

Continuously variable throughout its 3-to-1,000-vdc range, this new 500-ma lab power supply requires no derating. Advanced circuitry plus quality components and mechanical ruggedness provide exceptional reliability. Desig-

**One of these handy prepaid post cards will bring you detailed information**

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| 2 | 12 | 22 | 32 | 42 | 52 | 62 | 72 | 82 | 92 | 102 | 112 | 122 | 132 | 142 | 152 | 162 | 172 | 182 | 192 |
| 3 | 13 | 23 | 33 | 43 | 53 | 63 | 73 | 83 | 93 | 103 | 113 | 123 | 133 | 143 | 153 | 163 | 173 | 183 | 193 |
| 4 | 14 | 24 | 34 | 44 | 54 | 64 | 74 | 84 | 94 | 104 | 114 | 124 | 134 | 144 | 154 | 164 | 174 | 184 | 194 |
| 5 | 15 | 25 | 35 | 45 | 55 | 65 | 75 | 85 | 95 | 105 | 115 | 125 | 135 | 145 | 155 | 165 | 175 | 185 | 195 |
| 6 | 16 | 26 | 36 | 46 | 56 | 66 | 76 | 86 | 96 | 106 | 116 | 126 | 136 | 146 | 156 | 166 | 176 | 186 | 196 |
| 7 | 17 | 27 | 37 | 47 | 57 | 67 | 77 | 87 | 97 | 107 | 117 | 127 | 137 | 147 | 157 | 167 | 177 | 187 | 197 |
| 8 | 18 | 28 | 38 | 48 | 58 | 68 | 78 | 88 | 98 | 108 | 118 | 128 | 138 | 148 | 158 | 168 | 178 | 188 | 198 |
| 9 | 19 | 29 | 39 | 49 | 59 | 69 | 79 | 89 | 99 | 109 | 119 | 129 | 139 | 149 | 159 | 169 | 179 | 189 | 199 |
| 200 | 210 | 220 | 230 | 240 | 250 | 260 | 270 | 280 | 290 | 300 | 310 | 320 | 330 | 340 | 350 | 360 | 370 | 380 | 390 |
| 201 | 211 | 221 | 231 | 241 | 251 | 261 | 271 | 281 | 291 | 301 | 311 | 321 | 331 | 341 | 351 | 361 | 371 | 381 | 391 |
| 202 | 212 | 222 | 232 | 242 | 252 | 262 | 272 | 282 | 292 | 302 | 312 | 322 | 332 | 342 | 352 | 362 | 372 | 382 | 392 |
| 203 | 213 | 223 | 233 | 243 | 253 | 263 | 273 | 283 | 293 | 303 | 313 | 323 | 333 | 343 | 353 | 363 | 373 | 383 | 393 |
| 204 | 214 | 224 | 234 | 244 | 254 | 264 | 274 | 284 | 294 | 304 | 314 | 324 | 334 | 344 | 354 | 364 | 374 | 384 | 394 |
| 205 | 215 | 225 | 235 | 245 | 255 | 265 | 275 | 285 | 295 | 305 | 315 | 325 | 335 | 345 | 355 | 365 | 375 | 385 | 395 |
| 206 | 216 | 226 | 236 | 246 | 256 | 266 | 276 | 286 | 296 | 306 | 316 | 326 | 336 | 346 | 356 | 366 | 376 | 386 | 396 |
| 207 | 217 | 227 | 237 | 247 | 257 | 267 | 277 | 287 | 297 | 307 | 317 | 327 | 337 | 347 | 357 | 367 | 377 | 387 | 397 |
| 208 | 218 | 228 | 238 | 248 | 258 | 268 | 278 | 288 | 298 | 308 | 318 | 328 | 338 | 348 | 358 | 368 | 378 | 388 | 398 |
| 209 | 219 | 229 | 239 | 249 | 259 | 269 | 279 | 289 | 299 | 309 | 319 | 329 | 339 | 349 | 359 | 369 | 379 | 389 | 399 |

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| 8 | 18 | 28 | 38 | 48 | 58 | 68 | 78 | 88 | 98 | 108 | 118 | 128 | 138 | 148 | 158 | 168 | 178 | 188 | 198 |
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| 200 | 210 | 220 | 230 | 240 | 250 | 260 | 270 | 280 | 290 | 300 | 310 | 320 | 330 | 340 | 350 | 360 | 370 | 380 | 390 |
| 201 | 211 | 221 | 231 | 241 | 251 | 261 | 271 | 281 | 291 | 301 | 311 | 321 | 331 | 341 | 351 | 361 | 371 | 381 | 391 |
| 202 | 212 | 222 | 232 | 242 | 252 | 262 | 272 | 282 | 292 | 302 | 312 | 322 | 332 | 342 | 352 | 362 | 372 | 382 | 392 |
| 203 | 213 | 223 | 233 | 243 | 253 | 263 | 273 | 283 | 293 | 303 | 313 | 323 | 333 | 343 | 353 | 363 | 373 | 383 | 393 |
| 204 | 214 | 224 | 234 | 244 | 254 | 264 | 274 | 284 | 294 | 304 | 314 | 324 | 334 | 344 | 354 | 364 | 374 | 384 | 394 |
| 205 | 215 | 225 | 235 | 245 | 255 | 265 | 275 | 285 | 295 | 305 | 315 | 325 | 335 | 345 | 355 | 365 | 375 | 385 | 395 |
| 206 | 216 | 226 | 236 | 246 | 256 | 266 | 276 | 286 | 296 | 306 | 316 | 326 | 336 | 346 | 356 | 366 | 376 | 386 | 396 |
| 207 | 217 | 227 | 237 | 247 | 257 | 267 | 277 | 287 | 297 | 307 | 317 | 327 | 337 | 347 | 357 | 367 | 377 | 387 | 397 |
| 208 | 218 | 228 | 238 | 248 | 258 | 268 | 278 | 288 | 298 | 308 | 318 | 328 | 338 | 348 | 358 | 368 | 378 | 388 | 398 |
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Fill in your name, title, company and address.

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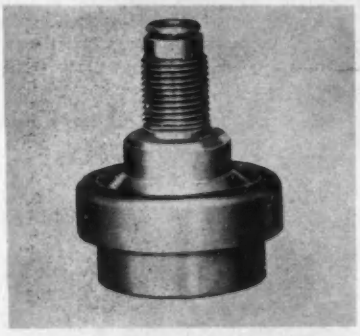
nated Model 62-126, the instrument sells for $695.

**Characteristics:**

Load regulation: 450 mv or 0.045 percent
Line regulation: 450 mv or 0.045 percent
Maximum ripple: 8 mv rms
Dimensions: 19 x 17 x 10½ in.
–Dressen-Barnes Corp., Pasadena, Calif.

**Circle No. 240 on reply card**

## ACTUATORS & FINAL CONTROL ELEMENTS



### SMALL BUT POWERFUL

"Vernatherm" is the name given to a new line of thermostatic, high-force actuators suited for a wide range of applications. Special materials used in their construction are highly sensitive to temperature changes. Miniature sizes, for example, can lift a 30-lb load one-third of an inch; large elements will move a 250-lb load ¼ in. –Detroit Controls Div., Detroit, Mich.

**Circle No. 241 on reply card**

### TWO-IN-ONE

A new six-way, four-position solenoid-operated selector valve, designated HP466100, combines the functions of two separate valves found in a 3,000-psi aircraft hydraulic system. The new design eliminates two solenoids, and two hydraulic line connections, thus reducing weight and increasing reliability.–Hydra-Power Corp., New Rochelle, N. Y.

**Circle No. 242 on reply card**

**we're not sure** *(yet)*

- ✓ WHAT YOU CAN USE THIS RELAY FOR
- ✓ HOW MUCH IT WILL COST
- ✓ EXACTLY WHAT THE STANDARD OPERATE & RELEASE VALUES WILL BE
- ✓ THAT THE SPECS, SIZE AND SHAPE WON'T CHANGE
- ✓ THAT IT WILL EVER GET INTO PRODUCTION

**we are sure**

- ✓ THAT THIS IS A DC VOLTAGE OPERATED, SPDT, HIGH RELEASE, DEVELOPMENTAL RELAY
- ✓ RELEASE CAN BE ADJUSTED UP TO 95% OF SPECIFIED OPERATE VOLTAGE (FROM 6 TO 24 VOLTS)
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- ✓ IT WOULD BE DANDY FOR MONITORING & CONTROLLING VOLTAGES IN AUTOMATIC BATTERY CHARGERS, POWER SUPPLIES, FILAMENT CIRCUITS, BATTERY-OPERATED TV SETS
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- ✓ THAT IT IS NOT SUITABLE FOR MILITARY ENVIRONMENT APPLICATIONS
- ✓ THAT IT'S KNOWN AS THE SERIES 111 RELAY AND THAT A SAMPLE IS AVAILABLE AT A PRICE

Maybe you twiddled the knob on the display of this relay in our booth at the last Old Campground meeting. If so, we hope you noticed on the meter just how close operate and release values can be. If you think you might be able to use such a relay, we'll gladly send additional particulars, with sure and not so sure portions clearly marked.

SIGMA

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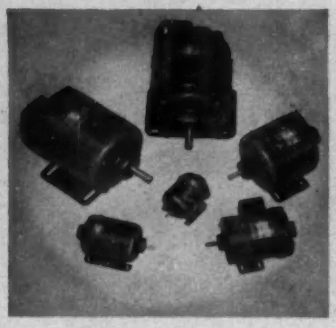
69 Pearl St., So. Braintree 85, Mass.
AN AFFILIATE OF THE FISHER-PIERCE CO. (Since 1939)

CIRCLE 118 ON READER-SERVICE CARD



# SMALL D-C MOTORS

## 1/100 TO 1 HP

**Speeds:** 860, 1140, 1725, 3450 rpm.

**Voltages:** 32, 115, 230 volts.

**Windings:** compound, shunt, and series.

**Enclosures:** for foot- or end-mounting; open, totally enclosed, explosion-proof, severe-duty, marine waterproof, Navy spraytight.

**Bearings:** Ball or sleeve.

**Special ratings** and speeds also available.

**Features:** Long life, high efficiency, quiet operation because of close tolerances, dynamic balancing, and spirally stacked punchings.

FREE BULLETIN — Write to Section 634-21, Schenectady, N. Y. GENERAL ELECTRIC

CIRCLE 119 ON READER-SERVICE CARD

# DRIES wet gas or air economically

PRITCHARD *Packaged* HYDRYER

Continuously removes moisture from gas or air stream at full line pressures. Protects processes, instruments, equipment at a fraction of the cost of field-built dryers. Dew points to -100°F. Sizes to 50,000 scfm. Saturated temperatures to 120°F. Pressures from 30 to 3500 psig.

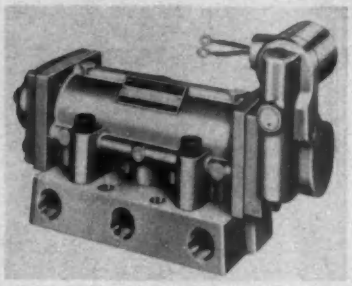
FREE BULLETIN—Gives application details, selection tables. Write for copy.

J. F. PRITCHARD & CO. OF CALIFORNIA

Dept. 119, 4625 Roanoke Parkway, Kansas City 12, Mo.

CIRCLE 120 ON READER-SERVICE CARD

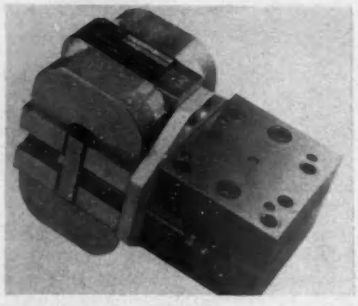

## NEW PRODUCTS



### ZERO LEAKAGE

Rugged construction, compact design, and zero leakage are combined in this new, full, ½-in. hydraulic control valve. Called the Poppet Pilot "B Type", the valve is available for single or double solenoid operation, operates on all customary ac and dc voltages; it can be furnished with two-way, three-way, or four-way action.—Hunt Valve Co., Salem, O.

**Circle No. 243 on reply card**



### BRUTE FORCE

This single-stage, four-way, flow-control valve has been designed for electrohydraulic servo systems where reliability and ruggedness are more important than size and power consumption. The power in its dc torque motor, which can exert more than 13 lb of force, comes into play when particle jamming or silting conditions are encountered; thus the valve can operate reliably in relatively contaminated fluids.

**Characteristics:**

Supply pressure: 50 to 1,000 psi
Maximum flow: 0.85 gpm
Internal leakage: 0.06 gpm, max
Power input: 5.5 watts, max
—American Measurement & Control, Inc., Waltham, Mass.

**Circle No. 244 on reply card**

# NO MORE EXTERNAL BOOSTER AMPLIFIERS...

## with the new combination resolver-booster by Reeves

**An outstanding advance in MINIATURIZATION without sacrifice of performance or precision.**

Shown FULL SIZE in the illustration above, this latest Reeves achievement in miniaturization for airborne applications takes up a fraction of the space occupied by a conventional resolver with external boosters. Yet performance, accuracy and dependability are in every way equivalent or better.

The new Reeves Combination Resolver-Booster consists of the time-proven R151 Precision Resolver with two PLUG-IN TRANSISTORIZED BOOSTER AMPLIFIERS built onto it as shown. The amplifiers provide standardization for transformation ratio and phase shift over a wide range of temperatures. Specifications given are maintained for production units without culling. Additional data on request.

### specifications

Transformation ratio: 1.000±.001
Phase shift: 0°±3'
Functional accuracy: 0.1%
Input impedance: over 8 megohms
Frequency: 400 c.p.s.±5%
Max. amplitude: 14 V. r.m.s.
Temp. range: —55° C. to 80° C.
Power requirements:
30 V. d.c. @ 6 ma. per amplifier

### REEVES CONTINUOUS RESOLVER CHECKER

Provides continuous 360° check on resolver functional accuracy, and yields permanent record of results.

**ENGINEERS:** *Rewarding careers at Reeves in the fields of radar, guidance, and computer systems.*

Reeves INSTRUMENT CORPORATION

**REEVES INSTRUMENT CORPORATION**

*A Subsidiary of Dynamics Corporation of America,* Roosevelt Field, Garden City, N. Y.

CIRCLE 121 ON READER-SERVICE CARD

NEW

TWIN CONTACT MINIATURES

DC-AC CHOPPERS

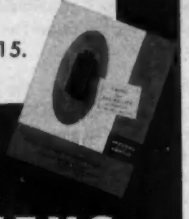
Eleven types, both single and double pole.

Long life.

Low noise level.

Extreme reliability.

Write for Catalog 515.



STEVENS INCORPORATED ARNOLD

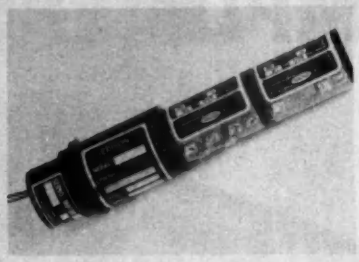
7 ELKINS STREET
SOUTH BOSTON 27, MASS.

S-A-14

CIRCLE 122 ON READER-SERVICE CARD

## NEW PRODUCTS

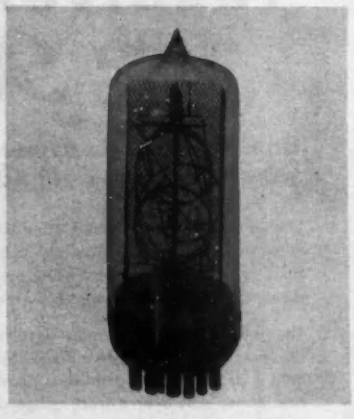
### COMPONENT PARTS



**IN-LINE DESIGN**

This space-saving, in-line subsystem consists of a Size-10 servomotor, gearhead with clutch, and two precision potentiometers. It represents just one of many such modular units available from this manufacturer. Similarly-designed units could contain any component adaptable to rotary operation, such as resolvers, potentiometers, synchros, and tach-generators.—Thomas A. Edison Industries, McGraw-Edison Co., West Orange, N. J.

**Circle No. 245 on reply card**



**10-DIGIT READOUT**

Pictured is the Digitron, a new cold-cathode register tube for indicating the digits 0 through 9. Maker claims the new tube will extend the usefulness of the versatile Dekatron counting tube by providing a more efficient direct readout. Chosen digit may be illuminated by grounding the appropriate cathode; or its cathodes may be connected to the anodes of 10 cold-

DISCOVER the DI/AN DIFFERENCE

*. . . in shift-register modules, for example:*

Our "Thimbles" are tiny, rugged, encapsulated packages, containing a complete, reliable, magnetic-core-transistor shift-register circuit. Widest operating margins of any shift-register technique! Build complete Thimble registers (or buy them from us) at *lower cost per bit* than with any other module.

Compatible accessory circuit modules available from stock!

Write for Catalog E-591.

. . . not just a "core in a package", but a complete working circuit . . . you furnish only the signals! . . . not a "power-hound": requires much less driving power, and no standby power.

di/an

ALSO PRODUCES:
BUFFER STORAGES
RANDOM-ACCESS CORE MEMORIES
MAGNETIC-LOGIC MODULES
DIGITAL/ANALOG SYSTEMS

. . . ALL WITH THE DI/AN DIFFERENCE

DI/AN CONTROLS, INC.
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40 Leon Street
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CIRCLE 123 ON READER-SERVICE CARD

TI announces

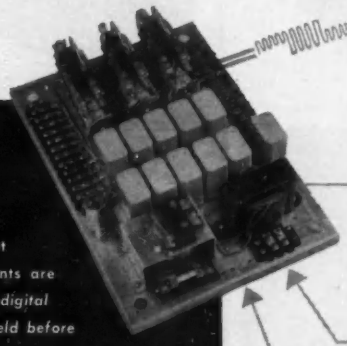
# DATA-MAC

## Digital Automatic Measurement — Alarm — Control

*New Advanced Instrumentation for* AUTOMATIC

- Lease Operation
- Refinery Operation
- Plant Supervisory Control
- Pipe Line Operation

**TRANSCEIVER CONTROL UNIT** generates dialing impulses, decodes, checks all transmissions, presents information on easy-to-read universal data display panel. The TCU also feeds printers, typewriters, perforators, loggers or other recording devices.



**TELEMETERING** of control, data, and monitoring information is accomplished by **2-wire link**, leased line or radio with transmissions in **error-safe** digital code, checked at least three ways. "Plus-Minus" system eliminates possible "Long-Short" ambiguity. No vacuum tubes are used anywhere in the system.

FIELD SELECTOR UNIT has 100 point capacity. Points are identified *in digital code from field before control power is actuated.* Matrix power wiring allows 20 wires to connect 100 points.

### CONTROL

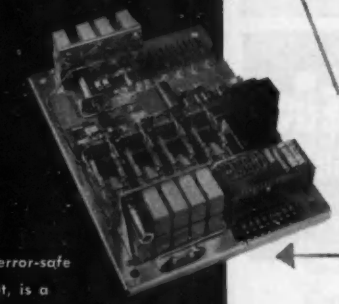
**VALVES, SET-POINTS** and similar devices are controlled by either simple "ON-OFF" or three-way "UP-DOWN-STOP" operation.

**PUMPS, MOTORS** and other units with simple "ON-OFF" control require only the connection of pilot relays or starters to DATA-MAC.

### READOUT

**LIQUID LEVEL** measurement to 1/16-inch accuracy is provided by proven DATA-GAGE techniques.*

**ACCUMULATORS** on Positive Displacement meters, Positive Volume units, or similar integrating counters are read out in **error-safe** binary decimal code including all significant digits.



ANALOG INPUT UNIT to generate error-safe digital output, is a self-balancing, three-decade (0.1% accuracy) Wheatstone Bridge.

### ALARMS

**ALARM** switch position changes are immediately transmitted in **error-safe** digital code. DATA-MAC differentiates between alarm conditions and faulty wiring with **fail-safe** operation. ONLY TWO WIRES REQUIRED FROM FIELD SELECTOR TO TRANSCEIVER UNIT.

### MEASURE

**ANALOG TRANSDUCERS** read temperature, pressure, flow rate, speed, pH, B.S. & W., voltage and other variables.

*Licensed under Sun Oil Company patents.

**DATA-MAC CANNOT GIVE FALSE INFORMATION!**

***For complete information on this modern control and measurement system, write for Bulletin M-602.***

**TEXAS INSTRUMENTS**
**INCORPORATED**
**INDUSTRIAL INSTRUMENTATION DIVISION**
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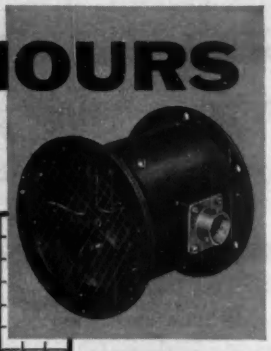
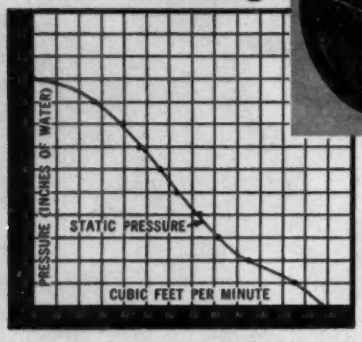
- Seismic Systems
- TI Worden Gravity Meters
- "recti/riter" Recorders and Accessories
- Automatic Test Equipment

CIRCLE 124 ON READER-SERVICE CARD

MORE THAN
3000 HOURS
at 125°C
...and still running!






NEW
Tube
Axial
Blower

Here's a miniature tube axial blower that withstands the most rigid MIL specifications! Tests at 125°C and under extreme shock and vibration conditions, have exceeded 3000 hours, with no sign of failure. The motor is EAD's rugged, 400-cycle 208-volt induction motor, run at a constant speed of 7200 rpm. Write for complete information on this peak-performance blower assembly,

EAD EASTERN AIR DEVICES, INC.
*Subsidiary of Norbute Corporation*
375 CENTRAL AVE., DOVER, NEW HAMPSHIRE

CIRCLE 125 ON READER-SERVICE CARD

here is the world's smallest and simplest strip chart recorder!

- AMPLE STORAGE: Contains 63-ft. chart roll, or 31 days' recording at one inch per hour. Useful chart width 2 5/16".
- ACCURATE: Galvanometer pointer swings free for maximum accuracy, being clamped briefly for marking.
- INKLESS: Recording process is completely dry, utilizing special pressure sensitive paper. Method provides remarkable definition.
- RECTILINEAR: Advanced design provides true rectilinear recording free from distortion.
- RELIABLE: Positive synchronous motor drive with sprocket engaging holes in paper for accurate time indication.
- VERSATILE: Portable or panel mounting models. Stocked in a variety of scales and chart speeds.

WRITE TODAY FOR LITERATURE

*Subject to change without notice.

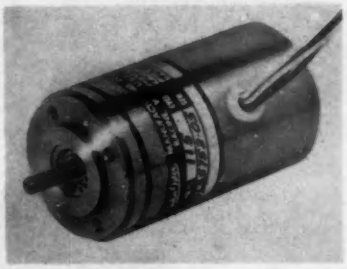
rust industrial co., inc.
130 Silver Street, Manchester, N. H.

CIRCLE 126 ON READER-SERVICE CARD

## NEW PRODUCTS

cathode or thermionic tubes to display a state of count. Maximum cathode current is 9 ma; minimum voltage necessary to insure breakdown, 220 volts.—Baird-Atomic, Inc., Cambridge, Mass.

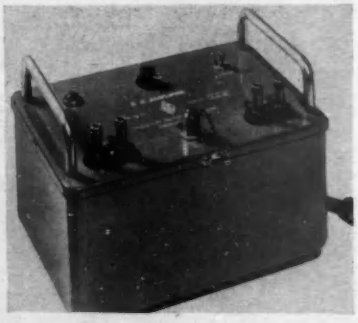
Circle No. **246** on reply card



### VISCOUS-DAMPED

This adjustable, viscous-damped, size-11 motor is said to be smaller, lighter, and more economical than a motor tachometer for feedback damping applications. Called the Type 5752-05, it presents no null or phasing problems in the feedback loop, permits damping and gain to be adjusted independently. No-load speed may be set anywhere between 4,800 and 7,300 rpm, depending on system requirements.—John Oster Mfg. Co., Racine, Wis.

Circle No. **247** on reply card



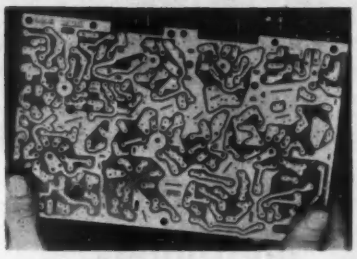
### CHOPPER-STABILIZED

The new M-10 multipurpose, chopper-stabilized, dc amplifier provides a current output proportional to a millivolt input, making it suitable for a number of lab and industrial applications. For example, with inputs of 0 to 10 mv at an input impedance level of 10 megohms, the amplifier will drive a 0-to-1-ma meter-movement recorder. Inputs in this case might be from

strain gages, thermocouples, or other transducers in the 0-to-2-cps frequency range. With suitable shunts, it becomes a current or voltage amplifier. Accuracy is within 1 percent; linearity, within 0.5 percent. Drift is less than 50 μv referred to the input. Unit sells for $135.–Houston Instrument Corp., Houston, Tex.

**Circle No. 248 on reply card**

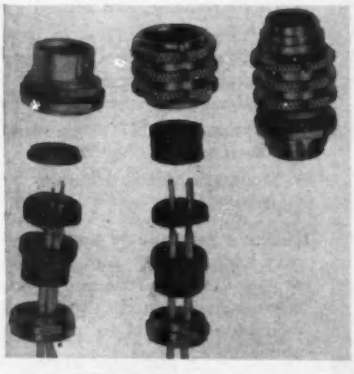
## ACCESSORIES & MATERIALS



### FLAME-RESISTANT

A new flame-resistant laminated plastic, designated Phenolite grade XXXP-475, offers excellent electrical properties, high insulation resistance, and low moisture absorption, provides flame retardant characteristics of paper base epoxy grades at much lower cost. Designed primarily for printed-circuit applications, the new material is available in thicknesses from 1/32 to 1/4 in.; sheet sizes are 39 by 47 in., and 39 in. square.—National Vulcanized Fibre Co., Wilmington, Del.

**Circle No. 249 on reply card**



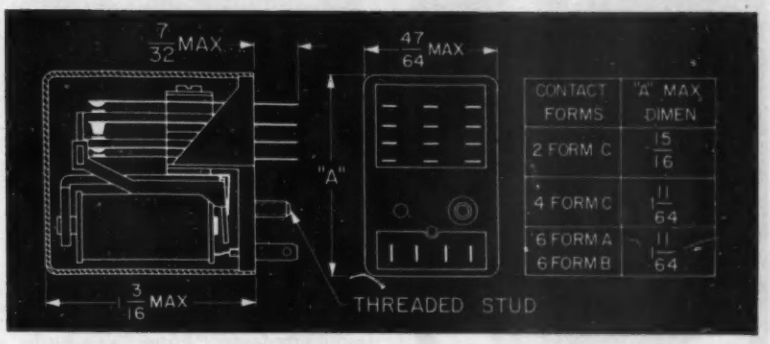
### NO SOLDER POTS

The new DS Series of "snap-in" miniature electrical connectors features removable contacts, silicone inserts, and crimp-type terminations that replace solder pots. Vibration-damped, the new connectors offer continuous


# MINIMUM SIZE
# Maximum Dependability
# LOW COST

ACTUAL SIZE

The new T-154 relay
is now being manufactured by
Allied Control at Plantsville, Conn.




**General Features:**

**Operate Sensitivity:**
From 90 milliwatts for 1.3 ohm coil to 160 milliwatts for 15,000 ohm coil up to 2 Form C

From 200 milliwatts for 1.3 ohm coil to 400 milliwatts for 15,000 ohm coil up to 6 Form A

**Coil Resistance:** Up to 15,000 ohms

**Coil Voltage:** Up to 140 volts d-c

**Contact Rating:**
Low Level to 1 ampere 29 volts d-c or 115 volts a-c resistive.
5 ampere contacts are available

**Contact Arrangement:** Up to 6 Form A, B and 4 Form C

**Operate and Release Time:** 7 milliseconds max. at 1 watt

**Shock:** 10 g's

**Vibration:** 10 to 55 cps at .062" double amplitude

**Enclosure:** Dust proof and hermetically sealed

**For complete information write for Bulletin T154**

**ALLIED CONTROL**

ALLIED CONTROL COMPANY, INC., 2 EAST END AVENUE, NEW YORK 21, N. Y.

AL 109

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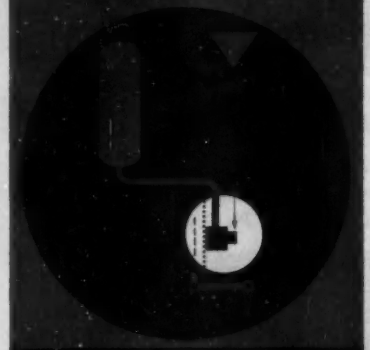
Atchley

ELECTRO-PNEUMATIC
SERVOVALVES

FIRST IN RELIABILITY



MODEL 615
Weight 13 ounces
Shown ½ size

Unique jet construction permits passage of particles as large as 200 microns through both the first and second stages without malfunctioning.

**Other features include:**

Single source of gas in first stage eliminates possibility of unbalance or "hard-over" signals due to gas contamination.

Second stage precisely controlled by a push-pull, frictionless, force feedback servo.

Model 615 has double the flow capacity of the smaller Model 610.

**For more information, write for Data File CE-683-1.**

*Raymond Atchley, Inc.*
2140 SAWTELLE BOULEVARD
LOS ANGELES 64 CALIFORNIA
TELEPHONE • GRANITE 9 8676

CIRCLE 128 ON READER-SERVICE CARD

## NEW PRODUCTS

dielectric separation with no voids and permit no air leakage at 30 psi differential. Temperature range is minus 100 to over 300 deg F. Units are available with 7, 19, and 37 pin and socket arrangements, and are designed to mate with the company's earlier DM Series. They meet or exceed MIL-C-5015.–The Deutsch Co., Los Angeles, Calif.

Circle No. **250** on reply card

### AIDS INSPECTION

Dielectric Gel, a new silicone potting material, has a number of interesting properties. Applied as water white liquid with the viscosity of molasses, the material readily surrounds the components that are to be potted, and exerts no damaging stresses either during or after cure. Curing time can be varied from 30 min to 48 hours. Since it is completely transparent, circuits can be traced visually. Even more important is the fact that test probes can be inserted through the gel to make electrical tests. After the probes are removed, the material immediately "heals" itself. Resiliency of the material serves to protect parts from both shock and vibration.–Dow Corning Corp., Midland, Mich.

Circle No. **251** on reply card

### INSTRUMENT CASES

A new line of custom-built instrument cases features rugged construction. Cases are fabricated from Warlite, a melamine plastic bonded to a composition base. Birch, mahogany, walnut, and other wood grains are among 150 patterns available. Crack and stain resistant, the material is said to be stronger and more durable than either wood or metal.–Warwick Products Co., Cleveland, O.

Circle No. **252** on reply card

**The plus is precision!**

# NEW analog multiplier-divider by Philbrick

This is Philbrick's K5-M — which provides improved long term stability. Accuracy, including drift, is better than 0.10v in all 4 quadrants.

**FEATURES:**

- Accepts 3 variable inputs $e_1, e_2, e_3$ and yields $e_1e_2/e_3$
- 3-digit decade provides adjustable scaling voltage
- Useful response even beyond 10 kcps.
- Needs no auxiliary equipment to obtain products, ratios, squares, square roots, etc.
- Requirements: 115vac filament power; 110ma at ± 300vdc
- Mounts on standard 7″ rack panel

Here's a new and higher degree of *precision*, *speed*, and *flexibility* at your fingertips for analog computation, correlation, precision modulation, control, many other applications.

*For full informaton, write:*
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**PHILBRICK**
RESEARCHES, INC.
*285 Columbus Ave., Boston 16, Mass.*
*COmmonwealth 6-5375*

THE ANALOG WAY IS THE MODEL WAY

CIRCLE 129 ON READER-SERVICE CARD

lurgy, reactor design, instrumentation and control, heat transfer, and gas dynamics. E. Justin Wilson Jr., who joined the parent company in 1954, has been appointed ATL president.

**Elion Instruments, Inc.,** to do research in, develop, and produce ultrasonic transducers, electron pin resonance equipment, and X-ray microanalyzers—in Bristol, Pa. Other activities of the new firm include consulting and development services in electronic plasmas, high-voltage engineering, and medical electronics. H. A. Elion, formerly group leader for advanced development of scientific and industrial instruments at RCA, is president, and Robert J. Zeigler is vice-president and chief engineer.

**Propulsion Test Facilities, Inc.,** formed as an affiliate of MB Mfg. Co. to perform complete environmental tests on aircraft and missiles—in New Haven, Conn. Systems oriented, the new firm will not only do environment testing, but will design and build test facilities. President is George Mettler, MB president.

**Rheem Semiconductor Corp.,** organized by Rheem Mfg. Co. and a scientific and engineering group headed by E. M. Baldwin, formerly general manager of Fairchild Semiconductor Corp., to develop and manufacture semiconductor devices—on the San Francisco peninsular. As vice-president and general manager of the new subsidiary, Baldwin will direct a 12-man team, including a unit that came over with him from Fairchild, in advancing the state of the art as it applies to silicon diodes, transistors, and other items. Baldwin has also been with Hughes Aircraft and with Carnegie Tech's Research Center.

**Silicon Transistor Corp.,** which is already producing silicon diodes and is on the engineering pilot run of silicon power transistors — in Carle Place, Long Island, N. Y. President and chief engineer of the new firm are, respectively, Harold Sandler and Randolph Bronson.

**Thermocal. Inc.,** a new specialty-switch manufacturer—in Santa Monica, Calif. R. F. Denton is acting general manager and John Kennedy is vice-president.

**Consolidated Systems Corp.,** representing a corporate status for Consolidated Electrodynamics' Systems Div.—in Monrovia, Calif. The new, wholly-owned subsidiary was formed principally to "put the company's systems business in a position to take full advantage of the mushrooming


MOST MAJOR U.S. POWER PRODUCERS REDUCE COSTS with PANALARM ANNUNCIATORS

MAXIMUM INFORMATION on all process variables . . . the result of 10 years system engineering by Panalarm and major power producers. That's why Universal Series 50 is the power industry's most informative annunciator. Trouble anywhere is signalled instantly—*before* it can grow big and expensive. "Off-normals" are pinpointed instantly, accurately for fast remedial action, reducing costly "outage" losses.

Economical, highly flexible design facilitates system expansion. Can be simply adapted to your exact requirement, avoiding costly custom designing. Proven components—e.g., almost 1,000,000 dependable Panalarm developed relays have been used in Panalarm annunciators.

Ask your nearby Panalarm sales engineer to show you why Universal Series 50 is the power industry's No. 1 annunciator choice . . . how its adaptablility and reliability can help increase your profits . . . by producing maximum information and reducing costly "outages." No obligation, of course.

*Write for Catalog 100 B today.*

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DIVISION OF
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CIRCLE 130 ON READER-SERVICE CARD

Here's data on the *New*

**DIAL HEAD AGASTAT®**

**time/delay/relays**

These relays have recently been re-designed—improved in performance *and* appearance. So you'll want up-to-date specs.

This free folder gives complete details on all models. In it you'll find operating specs, timing ranges, contact capacities, dimensions, diagrams of contact and terminal arrangements, and data on mounting and installation accessories.

*For your copy, write:* Dept. A34-520.

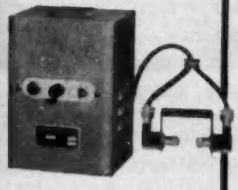
AGA **ELASTIC STOP NUT CORPORATION OF AMERICA**

Elizabeth, New Jersey

CIRCLE 131 ON READER-SERVICE CARD

**POST DECITRON ELECTRONIC PRODUCTS**

**Photoelectronic Controls**



**Model K-1 with Miniature Photohead**

This is a general purpose photoelectric control whereby the interruption of a light beam in the photohead closes a relay which can be used to activate an external circuit.

**Model K-3**

The K-3 control differs from the K-1 in that the output relay will not energize for each interruption of the light beam, but only if interruptions cease. Can be used to detect "flow" stoppage.

**Model H-21-C**

The compact, long life, *miniature* photohead . . . ideal for mounting in limited space. May be furnished with alignment brackets to insure proper relation of light source and receiver.

Decitron

**ELECTRONIC PRODUCTS DIVISION**

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market for its services", said CEC President Philip S. Fogg. The Systems Div. was formed in 1954 and in 1958 grossed $6.4 million in sales. Its forte is custom-engineered instrumentation and control systems for specialized customer needs.

**Kollsman Motor Corp.**, formed as a subsidiary of Standard Coil Products Co., Inc.—in Melrose Park, Ill. Another Standard Coil subsidiary, Kollsman Instrument Corp., is located at Elmhurst and Syosset, N. Y. The new subsidiary will concentrate on the Kollsman line of special-purpose precision electrical motors, expanding the line, enlarging present markets, and creating new ones. It is aiming at a year-end sales target of $5 million.

**The Oxford Corp.**, organized by former employees of Bell Aircraft Corp. to produce specialized instrumentation, automatic controls, and optical systems—in Buffalo, N. Y. George A. Reed, who had been a section manager for automatic control equipment in Bell Aircraft's Avionics Div., is president of the new firm, and James A. Mott, a former project engineer, is vice-president.

—**Elliott Nucleonics, Ltd.**, a new subsidiary formed by the Elliott-Automation Group (CtE, March '58, p. 48) to take over the nuclear business of Elliott Brothers, Ltd.—in London, England. Initial interests will be those of Elliott Brothers: control and instrumentation of nuclear reactors and power stations and associated chemical plants, and uses of radioactive isotopes in industrial processes. Two specific projects are already under way, one for Britain's Central Electricity Generating Board and the other for a gas-cooled reactor.

## Engineer's Placement Guide Is Out in a New Edition

The 1959 edition of the technical placement reference, *Engineers' Job Directory*, is announced by its publisher, Decision/Inc., of Cincinnati, Ohio. Subtitled *Placement Guide for Executives, Engineers and Scientists*, the 72-page directory contains the following information about 1,000 companies: their address and telephone number, the type of industry they are engaged in, their products and number of employees, and the names of the persons to contact. Copies sell for $5 each, and may be obtained by writing Decision/Inc., at 4601 Red Bank Road, Cincinnati 27, Ohio.

## IMPORTANT MOVES BY KEY PEOPLE

### Bayliss Oversees Engineering at Convair; Fox Moves Up

Ralph L. Bayliss has moved up to director of engineering for Convair, and William W. Fox has succeeded him as chief of the San Diego division of the General Dynamics unit. Fox, in turn, has been replaced as assistant chief for product design at San Diego by Richard P. White, formerly chief technical engineer. Bayliss, who fills a new post, joined Convair at San Diego in 1936, rose through the positions of chief of aerodynamics, chief of preliminary design, chief development engineer, and assistant chief engineer. He has been chief engineer since 1955. Fox has been with the San Diego division since 1943, became assistant chief engineer last year. White joined in 1951, moved into his most recent position in 1957.

### K. D. Garnjost Appointed Chief Engineer at Moog

The new chief engineer of Moog Valve Co., Inc., is K. D. Garnjost, most recently technical assistant to the president of Moog. He joined the firm in 1954 as director of research, later became chief systems engineer.

### Takashi Nakada Filling Fulbright Post at Purdue

Prof. Takashi Nakada of the Tokyo Institute of Technology is fulfilling a Fulbright assignment on the staff of the School of Engineering of Purdue University. He is a CtE author (CtE, Feb., p. 90).

### NRL's Robert M. Page Given Navy's Conrad Award

The 1959 Capt. Robert Dexter Conrad Award for outstanding achievements in research and development for the Navy has been presented to Robert M. Page, director of research of the U. S. Naval Research Laboratory. The award honors Page for his work in radio communications, radar, and electronics. In 1934, Page built the first pulse radar system for detecting aircraft in flight; in 1952, in recognition of this work and that which followed it, Hamline University of St. Paul, Minn., named its Electronics Laboratory after him.

Other honors conferred on Page include the Office of Scientific R&D's


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## WHAT'S NEW

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### RCA's Walter R. Beam to Take EE Helm at RPI

Walter R. Beam, formerly manager of microwave advanced development in RCA's Electron Tube Div., will succeed Harold N. Trevett as head of the Dept. of Electrical Engineering at Rensselaer Polytechnic Institute, when Trevett retires in July. The new associate head of the institute is Colon H. Dunn of the EE faculty. Beam has been with RCA since 1952, with the Electron Tube Div. since 1956. His staff of research scientists is responsible for several microwave amplifying and generating devices; he personally developed high-power, multiple-beam, electrostatic focus amplifiers. Trevett has been with RPI since 1920. He was named associate head of the EE department in 1953 and head in 1955.

### Other Important Moves

Stanford Research Institute has named **Allen M. Peterson** manager of the new Communications & Propagation Laboratory, and **F. J. Kamphoefner** manager of the Control Systems Laboratory. Peterson, who has been on the SRI faculty since 1950, will make his new duties concurrent with the old; Kamphoefner, with SRI since 1949, replaces **R. Manning Hermes**, who is directing an SRI research project at Fort Ord, Calif., for the Combat Development Experimentation Center.

**John K. Wetherbee**, who has been with Battelle Memorial Institute since 1953, has been named chief of its Systems Engineering Div. He helped organize this division in 1956, has been closely associated with its studies in analog simulation, human engineering, and servo and systems analyses. Before 1953, Wetherbee was with Link Aviation Corp.

**George Walker**, the new senior staff engineer in the Instrumentation Div. of Ampex Corp., comes from Magnavox Research Laboratories, where he had charge of the Mechanical Laboratory Section.

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ning for Dalmo Victor Co.'s Electronics Systems Div., **Marion A. Condie** will help plan R&D programs and will participate in preparation of technical proposals. He was most recently a supervisor in systems analysis for Ryan Aeronautical Co.

Bowmar Instrument Corp. has named **J. H. Mann** supervisor of mechanical design engineering for three divisions, Precision Counter, Gearhead, and Electromechanical, and **C. R. Jackson** director of manufacturing. Mann is a 20-year veteran with Magnavox, most recently was its chief mechanical design engineer; he will also head up a special electrical design section at Bowmar. Jackson comes from John Oster Mfg. Co., where he was head of manufacturing and engineering.

Most recently product manager of the Control Div. of Southwestern Industrial Electronics Co., a Dresser division, **Newton E. Armstrong** is now manager of the firm's Systems Development Div. His area will embrace instruments and systems for applying control in the chemical, petroleum-transportation, petrochemical, and process industries.

The new chief engineer, electronics, at Magnaflux Corp. is **Harold L. Garbarino,** formerly assistant manager of electrical engineering research at Armour Research Foundation. In his new position, Garbarino will direct development and improvement of instruments for eddy current nondestructive tests, precision magnetic-field measurement, and ultrasonic thickness measurement.

Servo Corp.'s new director of engineering is **Joseph Statsinger,** formerly assistant chief engineer for missile guidance for the Arma Div. of American Bosch Arma Corp. He was with ABA for 14 years.

**Larry McFarren,** most recently in the Specialty Electronic Components Dept. of GE, has been appointed chief engineer for International Resistance Co. at Burlington, Iowa. Before Joining GE, he was chief engineer of the Resistor Div. of P. R. Mallory & Co.

The Detroit Controls Div. of American Standard has named **John S. Amneus** manager of R&D, **Richard L. Campbell** divisional director of engineering, and **Thomas E. Noakes** chief engineer for Detroit Products. Amneus joined Detroit Controls in 1951 as chief mechanical engineer in the Research Div. Campbell has been with American Standard since 1925, with Detroit Controls since 1933; in his new assignment, he will direct product development and product engineering in plants in Detroit, Stamford, Conn., and Norwood, Mass. Noakes has been with the division since 1935.


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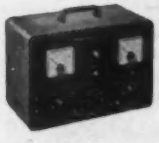

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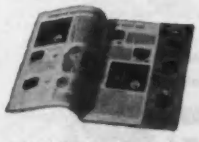

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## BULLETINS AND CATALOGS

(300) TAPE RECORDERS. Precision Instrument Co. Bulletin 55, 8 pp. Gives mechanical and electrical specifications for the Series PS-200 magnetic tape recorders. Typical unit weighs 65 lb (usual weight for a recorder of its ruggedness and accuracy: 1,000 lb) and uses only 250 watts (ordinary dissipation: 1,000 watts).

(301) TRANSISTOR CIRCUITRY. Navigation Computer Corp. Bulletin, 14 pp. This clear, well-organized booklet begins with basic applications in data handling, then suggests an available transistor switching circuit to fit. In each of the 24 cases presented, the most applicable unit is described clearly, its specifications are given, and its circuitry is shown.

(302) HONEYWELL LITERATURE. Minneapolis-Honeywell Regulator Co., Industrial Div. Bulletin G2-la, 22 pp. This is a double index; it pinpoints catalogs, bulletins, and data sheets in the first half, and articles in the Industrial Div.'s organ, Instrumentation Magazine, in the second. Education aids and other Honeywell services and literature also described.

(303) CALIBRATION MANUAL. Technique Associates, Inc. Bulletin, 16 pp. Three major sections tell how to use a new, three-unit calibration array for process control systems, give specifications for the three instruments, and show the many ways they can be arranged for measuring temperature, checking amplifiers or transmitters, etc.

(304) REACTOR CONTROL. Leeds & Northrup Co. Technical Publication N-03(1), 18 pp. Covers present reactors —the pressurized water and boiling water reactors, the Sodium Reactor Experiment —and reactors of the future, explains, by means of generous diagrams, how a nuclear power plant operates, how it is instrumented, and how it is controlled.

(305) DISPLAYS & PUSHBUTTONS. Minneapolis-Honeywell Regulator Co., Micro Switch Div. Catalog 67, 20 pp. A bright, attractive description of a group of modular indicators and pushbuttons designed particularly for electronic data-processing systems, computers, graphic flow panels, business machines, etc. Indicating and switching devices can be combined in a single unit, in a variety of mounting and layout schemes.

(306) SWITCHES & ACTUATORS. Electrosnap Corp., Switch Div. Catalog ES-59, 52 pp. This bound reference work contains terminology definitions, specifications, dimensional drawings, photos, and modification data. Principal subjects are sub-subminiature "peanut" switches, subminiature snap-action switches, single-pole and multiple-pole types, and actuators.

(307) ON ELECTRIC QUANTITY. General Electric Co. Bulletin GEA-6788, 15 pp. This one concentrates on measurement systems in aircraft. Main interest is ac and dc panel instruments, current transformers, and ground maintenance equipment.

(308) ABOUT FERRITES. General Ceramics Corp. Paper, 6 pp. Square-loop ferrite materials are the heart of the mem-

ory in most large, high-speed digital computers. They are discussed here by Ernest Albers-Schoenberg, their discoverer, who is vice-president and director of research of General Ceramics.

(309) ROBBINS PRODUCTS. Robbins Aviation, Inc. Catalog 1159, 74 pp. Big, clear schematics and drawings, specification tables, and text cover a large number of Robbins devices. General categories: dehydration, refrigeration, mechanical filters, driers and purifiers, and vapor indicators. There is also a price list.

(310) ELECTRIC EYES. Photomation, Inc. Bulletin 577, 6 pp. Deals with miniature instruments for measuring, recording, and registration, describing applications and construction, and illustrating installation. Also compares the color ranges of the human eye and the electric one.

(311) THE INDUCTOSYN. Farrand Controls, Inc. Bulletin ER-312/I, 32 pp. The title of this bulletin is "Principles and Applications", and the subject is an automatic machine-tool control system for micropositioning. Two types are described: rotary, accurate to better than 1 sec of arc, and linear, accurate to 0.0001 in.

(312) PRESSURE SERVOVALVES. Moog Valve Co. Catalog 150, 7 pp. Presents operating principles, design features, and performance characteristics of the Moog line, explains how the valves can be used in closed-loop systems to control load acceleration, and as force transducers or pressure regulators. Includes cutaway photo, schematic diagram, and performance curves.

(313) SELECTING A STRAIN GAGE. Stein Engineering Services. Article, 24 pp. Here is a reprint from Vol. II, No. 1, of "Strain Gage Readings", a periodical devoted to strain gages, strain-gage transducers, and associated equipment, comparing the characteristics of resistance strain gages made by eight U. S. manufacturers. Specifies criteria for selecting strain-gage properties.

(314) SERVOAMPLIFIERS. Magnetic Amplifiers, Inc. Bulletin S-961, 8 pp. Photos, diagrams, charts, and accompanying text detail the "Advanced Design B" line of high-power, transistorized servoamplifiers for industrial and military use. The amplifiers can have from one to four stages, use ac or dc inputs, and have supply frequencies of 60 or 400 cps.

(315) FOR DISSOLVED OXYGEN. The Hays Corp. Three-bulletin package, 12 pp. Describes the operation of the new Hays dissolved oxygen meter and the three basic instruments that make it up. The three are a contact sampler, a Magno-Therm analyzer, and a recorder; specifications of each are included.

(316) SPECTROPHOTOMETER. Applied Physics Corp. Bulletin 114, 12 pp. Discusses features, performance, construction, operation, and accessories of the Cary Model 14 recording spectrophotometer, used for rapidly recording spectra where there is a demand for high precision and accuracy.

(317) CYLINDERS. Petch Mfg. Co.


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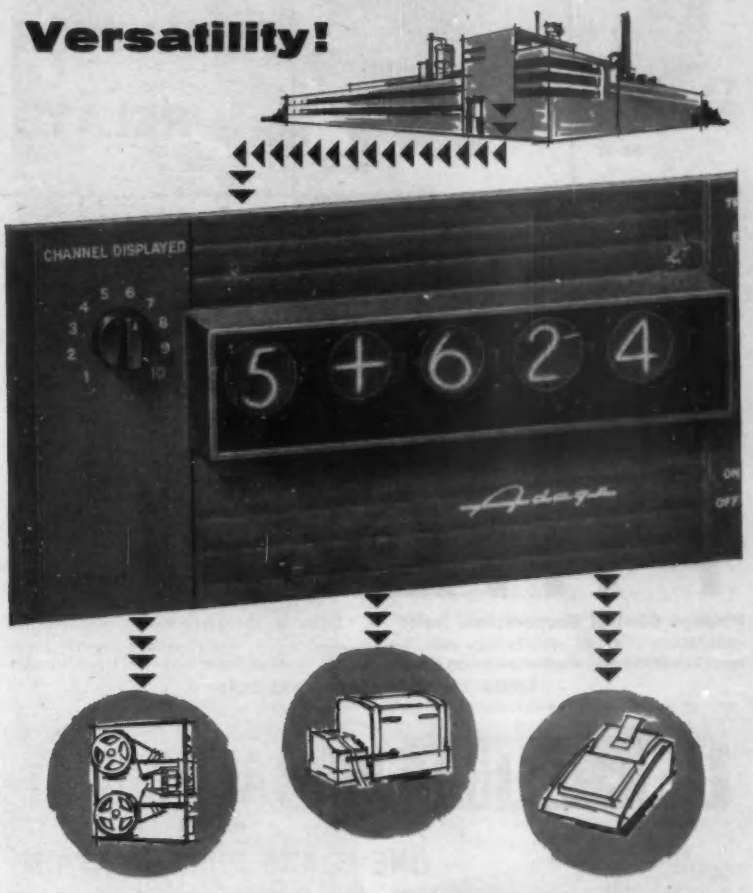


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## Bulletins & Catalogs

Brochure 8a/Pet, 16 pp. Covers approximately 50 air and hydraulic cylinders for low and high pressure, treating these dimensions: psig, bore size, rod diameter, rod-thread size, and thread length. Boosters and tanks, valve units, and gages finish the brochure.

(318) GALVANOMETER. Leeds & Northrup Co. Data sheet ED2(1), 2 pp. Described here is a "guarded" galvanometer, a self-contained lamp and scale instrument. Data sheet shows how it can be used with a potentiometer, a Wheatstone bridge, and other units, gives a schematic of it and its complete specifications.

(319) HANDLING ANGULAR DATA. General Electric Co. Bulletin GEA-6675, 16 pp. A discussion of the GE line of Selsyns and synchros, highly accurate electromagnetic transmitters of electrical angular data between two or more points. Generators, motors, control transformers, differential motors, and tandem Selsyns are covered. There are schematics, line drawings, tables and charts.

(320) FROM MICRO SWITCH. Minneapolis-Honeywell Regulator Co., Micro Switch Div. Catalog 101d, 24 pp. Here is the representative Micro Switch line of precision snap-action and mercury switches. Covered are high-temperature, maintained-contact, explosion-proof, high-capacity, proximity, oil-tight, environment-free, and multicircuit types. Photos, dimensions, electrical ratings, and characteristics amplify text.

(321) PROGRAM OPTIMIZER. Computer Div. of Bendix Aviation Corp. Bulletin AR-118, 2 pp. Briefly describes POGO, a new automatic programming system for the G-15 digital computer.

(322) FOR RADIOACTIVITY. Nuclear-Chicago Corp. General Catalog R, 76 pp. This well-organized reference covers more than 125 products for counting, detecting, and recording radioactivity. Major new developments include a subcritical reactor for student training, two new ratemeters, a redesigned gamma-ray recording spectrometer, and a new automatic radiochromatogram scanning system.

(323) FERRITE CORES. Telemeter Magnetics, Inc. Catalog SL-106, 4 pp. Includes specifications for standard ferrite storage and switch cores, core arrays, sequential and conversion types of core storage buffers, transistorized computer memory modules, and the Data Translators for making systems compatible.

(324) THERMOCOUPLES. Tuttle & Kift Div. of Ferro Corp. Bulletin, 4 pp. Describes a line of current-carrying sheathed conductors and thermocouples. Tables provide dimensions and prices for two-wire iron-constantan, and two- and four-wire chromel-alumel types. Other sections deal with selection and application.

(325) POWER SUPPLIES. Kepco Laboratories, Inc. Catalog B591, 16 pp. Photos and specification tables supplement descriptions of a wide variety of voltage- and current-regulated power supplies. Two-page table of contents covers transistorized, vacuum-tube, and magnetic-tubeless types.

## ABSTRACTS

### Interesting Proposal

*From "A Sensing System for Punched Foil" by S. Morleigh. "Electronic Engineering", Vol. 31, No. 373, March, 1959, p. 140.*

Input information to digital computers can be handled in a number of ways, the punched card still being one of the best.

Present equipment for reading punched cards varies considerably in complexity. On a standard card, there are 80 columns and 12 rows, or 960 possible hole locations. Mechanical readers that locate all holes simultaneously are inherently complex. But readers using electrical contacts or photocells to sense hole positions also have disadvantages. For one thing, the number of sensing elements depends on the direction of card feed; it is 80 if the card is fed broadside and 12 if it is fed endwise. Also, electrical readers are often hampered by dust, dirt, and card fluff, while photoelectric readers require high-cost optical and amplifying systems.

The proposed device, a reader that handles cards fed endwise and continuous strips, would use capacitive sensing and require some modifications to the punched card.

The paper card in Figure 1 serves

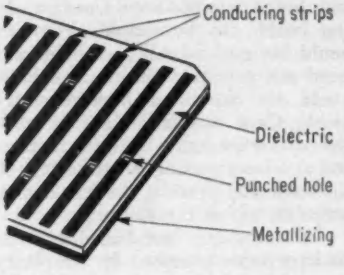


Fig. 1

as a dielectric between conducting strips on one side and a metallized or foil backing on the other. In the actual device the strips would be slightly narrower than the punched hole. Figure 2 (page 196), a cross-section through a conducting strip, shows the position of the sensing elements of pickups. As each strip moves under these elements, the punched hole divides it into two parts, $C_1$ and $C_2$, which are then used as two arms of a ratio detector or an elementary form of a capacitance bridge. Relative values of these capacitors would vary over a range of discrete steps corresponding to the hole positions.

Figures 1 and 2 show a card in

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Eastern achieved a 20% saving in hydraulic power supply capacity by the use of one of its own pulse length modulated single-stage servo valves, manifolded to each actuator. Zero first stage leakage, zero hysteresis, plus the high response and efficiency which characterize this valve contributed to the successful meeting of the demanding requirements.
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time constant: 0.1 sec.
max. actuator width: 1.25 in.
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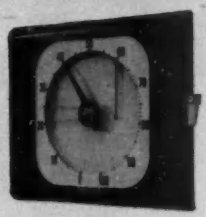

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## ABSTRACTS

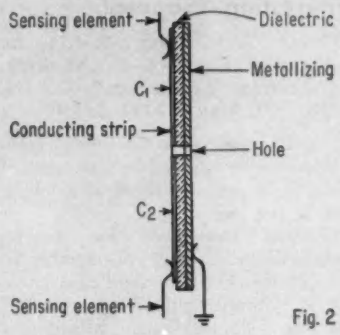


Fig. 2

which only one hole may be punched in a single column. For coding purposes, the rows on a standard card are usually divided into two sections or curtates, the lower curtate containing rows 1 to 9 and the upper curtate rows 10 to 12. Thus, the reader would actually require a discontinuity in the conducting strips between rows 9 and 10, and would use four sensing elements and two bridge circuits.

Error due to variations in dielectric thickness and width of the conducting strip will be tolerable.

Further modifications of the computer input system could make this proposal even more attractive. Card material could be supplied in rolls, eliminating any restriction on the number of columns used. Card punching could also be simplified: a slot could be used as well as a hole, and need not penetrate the card; or both could be cut by a high-frequency spark. Card material might be produced economically by using copper foil as a base, coating it with a high-K dielectric and printing the conducting strips on top of the dielectric.

The technique described does seem to have some promise. Its simplicity certainly should warrant further investigation of relative costs of complete installations and card manufacturing techniques.

### On-Stream Analysis

*From "An Application of Chromatographic Equipment—Monitoring the Performance of Four Refinery Fractionation Columns" by R. C. Halter and L. W. Pohler, both of Humble Oil & Refining Co. Paper presented at the 14th Annual Symposium on Instrumentation for the Process Industries, Texas A & M, Jan. 21-23, 1959.*

The authors discuss the installation of a plant-type chromatographic

analyzer and some of the problems this installation presented. The instrument has now been on stream since late September 1958, automatically analyzing, in sequence, samples from each of four plant towers. To check calibration, an operator can also select a standard sample for analysis. Each of the plant samples is analyzed for isobutane and normal butane content at the rate of one sample analysis every 10 min.

Information furnished by the analyzer has led to a much smoother operation, and an appreciable increase in isobutane recovery. Savings in the first 90 days of operation alone equalled the total cost of analyzer and sampling systems. This certainly establishes an economic justification for the installation.

Of all the instrumentation techniques used in making this installation, the most interesting are those dealing with the sampling and recording operations.

In the sampling system vapor samples are picked up at the fifth tray of the deisobutanizing towers at 120 to 140 psig and about 180 deg F. This point on the tower was selected to minimize the amount of heavy materials in the sample. (The analyzer itself was modified for precutter column operation to handle the small amount of heavy material that did come through with the sample.) At the towers the samples are filtered and expanded to 10 to 15 psig before entering steam-traced lines to the analyzer house. These pipe runs range from 125 to 350 ft, and are lagged to prevent condensation. Flow through this portion of the system is maintained at from 10 to 15 cfh, giving a maximum hold-up time of 1.3 min for the longest line.

At the analyzer house the main portion of each sample stream passes to the plant vacuum system, while about 150 cc per minute passes through a small line filter to a rotameter-differential relay flow-controller assembly. This assembly maintains a constant flow past a three-way solenoid valve to vents. These valves (one for each sample stream) are manifolded as shown in the figure on page 198, and actuated sequentially by the instrument's programming system. By-passing all streams to the vents assures fresh representative samples.

With no valves energized (positions are as shown, stream 1 furnishes the sample to the analyzer. Actually, only half the total flow in each sample stream passes to the ana-

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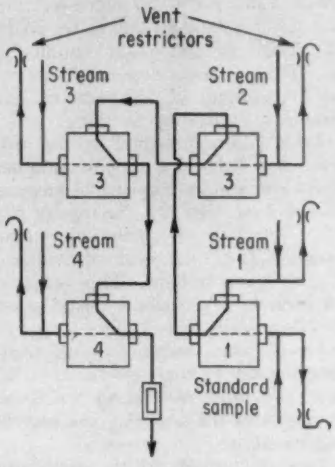
## ABSTRACTS

lyzer; the other half is vented along with the total flows in the other streams. Vent restrictions maintain




pressure only slightly above atmospheric, thereby eliminating leakage between streams. Programmed sequencing allows ample time for the stream switched into the system to flush out the previous sample before introduction of a sample into the analyzer column.

At the analyzer, a pressure gage was added to indicate the column back pressure, and thus the presence of any leaks that might develop in the carrier gas system. Two small rotameters at the base of the analyzer measure sample flow and the amount of carrier gas used to back-flush the precutter column.

Recorder and programming sections are located in the fractionating unit's control house, about 400 ft from the analyzer section. The programmer includes the timers, bridge power supply, and associated circuitry. A 0-to-10-mv recorder programmed to present data in bar-graph form is calibrated to record the amounts of iso- and normal butane on a liquid volume percent basis. The $iC_4$ is presented at a 0-to-50-percent full-scale sensitivity; the $nC_4$ at a 0-to-100-percent full-scale sensitivity. Numbered indicating lights show which stream is being sampled and a small printer permanently numbers the recordings for each tower. The recorder also indicates the amount of zero correction required in the bridge circuit. This provides a continual check on zero drift. A manual selector switch also permits presentation of complete chromatograms when desired.

## NEW BOOKS

### Frequency Response Updated

PROCEEDINGS OF THE SEMINAR IN SYSTEMS. *Edited by G. D. S. MacLellan, Cambridge University, London, and S. Mercer Jr. of the Applied Mechanics Dept., Michigan State University.* 170 pp. *Copies available from the Foundation for Instrumentation Education & Research, Inc., 335 East 45th Street, New York 17, New York.* $4.

The seven papers which form this volume were presented by their authors at a series of seminars in the Dept. of Applied Mechanics of the College of Engineering, Michigan State University, during the summer of 1958. The purpose of the meetings was to introduce members of the department to the rapidly developing field of systems analysis and design, and to stimulate a review and restatement of ideas and experiences by the authors, a widely diverse group of engineers already active in the field.

In line with these objects, Keisuke Izawa of Purdue University began by outlining fundamentals of the frequency-response technique and demonstrating its usefulness in the synthesis process. This paper also briefly reviews the history of the technique, present state of the art, and some of the future developments that will simplify its application.

Four of the remaining six papers discuss specific industrial applications of frequency-response methods. R. H. Kohr of General Motors Research Stall shows how frequency-response studies have been used to solve some of the stability and control problems associated with automobile design. R. I. Edleman, application engineer at Taylor Instrument, and C. M. Edwards of Bendix Aviation review applications in the fields of process control and machine tools. An application of frequency-response methods to the synthesis of an optimum missile guidance system is described in the second part of a paper by G. Allen Smith, research scientist at Ames Aeronautical Laboratory.

In the next to last paper Monsanto Chemical's J. O. Houngen tells how the chemical industries collect and use dynamic response data.

Finally, Prof. Ralph Kochenburger, University of Connecticut, outlines techniques for using frequency response in the analysis of nonlinear systems.

In all, these proceedings represent the thinking of some of the best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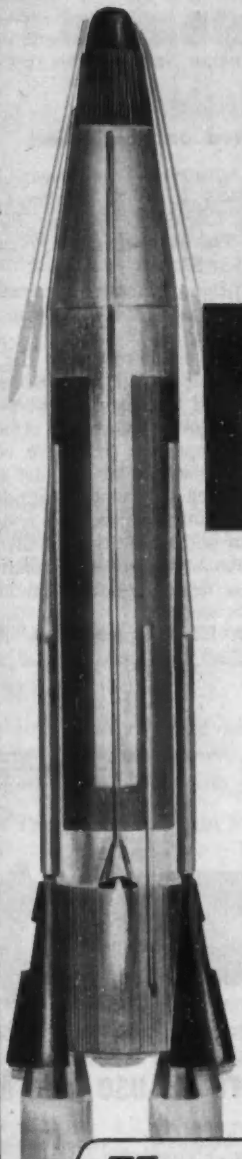

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talents in the field and provide at least a partial survey of work that has been done in the last five years. As such, the book should serve as a guide and reference, at least until the next major symposium on this subject.

## Revised and Expanded

ELECTRONIC MEASURING INSTRUMENTS. *E. H. W. Banner, Consulting Engineer. 496 pp. Published by The Macmillan Co., New York, 1958. $7.95.*

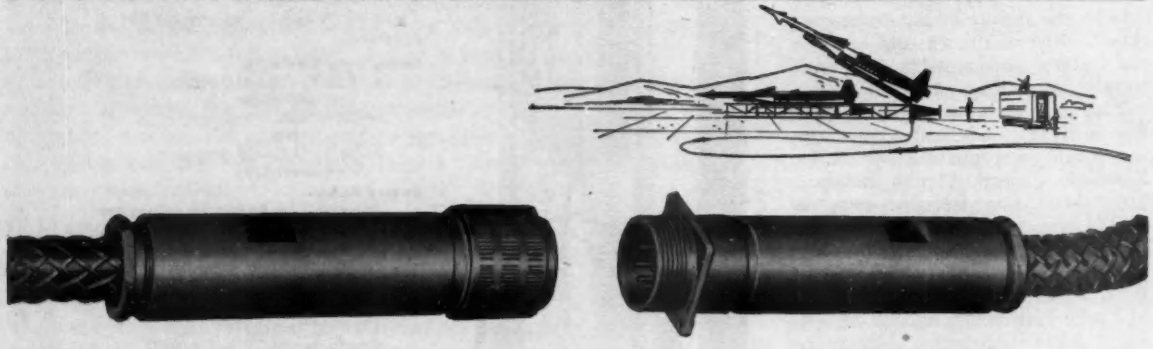
Written primarily for instrument engineers and students, this revised second edition of Banner's book represents a broad survey of the principles of electronic instruments, their types, and their component parts. It contains over 100 pages of material on developments that have occurred since publication of the first edition.

The first six chapters introduce indicating instruments, and review operation and application of their more important components. Radiation and particle detectors have been included in this section.

Part III, Chapters 7 to 12, deals with instruments using the devices described in the preceding chapters. The chapter on radiation measuring instruments should be of particular interest to an engineer entering the field of nuclear research. This part also contains a chapter on the design and application of a radiation thickness gage currently used in the paper and steel industries.

The fourth part of the book, or the last four chapters, gets into what the author terms quasi-electronic instruments—equipment that contains some electronic elements but can be classed by some alternative term, such as electromagnetic, electromechanical, etc. Devices covered in this section include various types of counters, strain gages, magnetic amplifiers, function plotters, vacuum gages, and moisture meters. The control engineer should be familiar with them all.

Obviously, a book of this size cannot possibly cover all the available equipment. The author has, however, done a fairly good job of including representative types of equipment. In all, the book should make a handy reference for the practitioner and the student alike.



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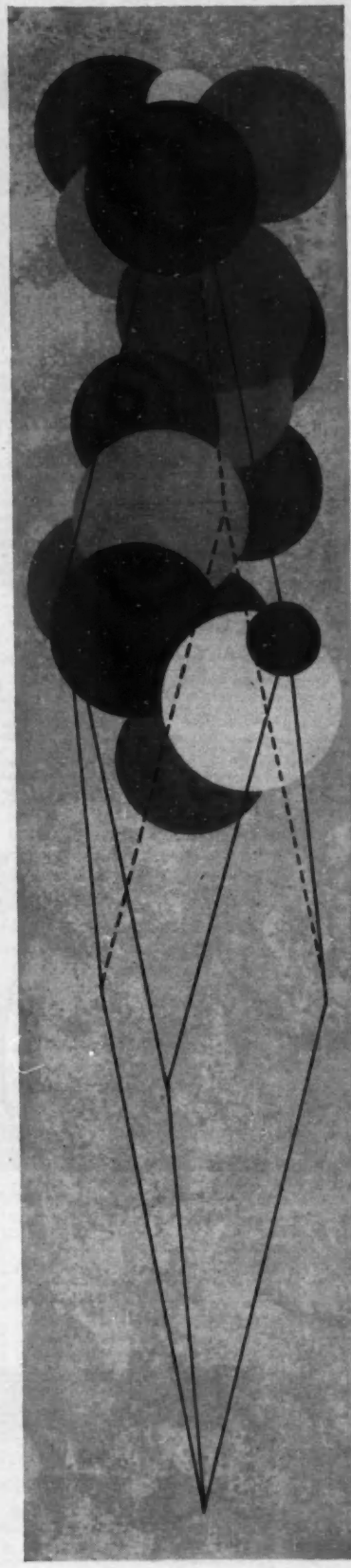

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**Fundamentals of Tie-Motor Control, 12 pp.** Although high-powered synchro-tie systems have been around for a long time, only recently has enough experience been logged to put their design on a scientific, rather than cut-and-try, basis. This reprint examines the types of motors that can be used in the light of the application characteristics, and considers the special

Continued on page 203

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*Continued on Page 204*


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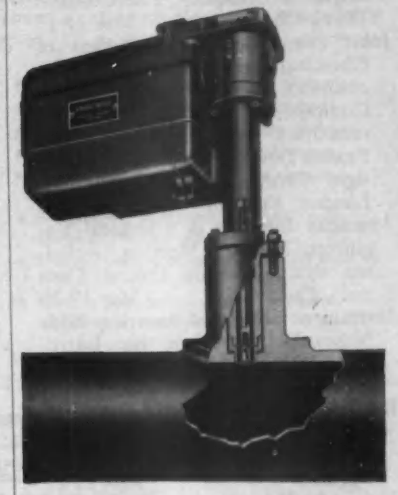

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## MEETINGS

### MAY

**American Institute of Electrical Engineers,** Joint Conference on Automatic Techniques, Pike-Congress Hotel, Chicago. May 11-13

**Joint Symposium of Institution of Chemical Engineers,** Society of Instrument Technology, The British Computer Society; Theme: Instrumentation and Computation in Process Development and Plant Design, Central Hall, Westminster, London, England May 11-13

**American Institute of Chemical Engineers,** National Meeting (including Symposium on Process Control), Kansas City May 17-20

**Instrument Society of America,** Fifth National Symposium on Instrumental Methods of Analysis, Shamrock-Hilton, Houston May 18-20

**British Institution of Electrical Engineers,** International Convention on Transistors, Earl's Court, London, England May 21-27

**National Telemetering Conference,** sponsored by ISA, AIEE, IAS, and ARS, Cosmopolitan Hotel, Denver May 25-27

**American Society of Mechanical Engineers,** Design Engineering Conference, Convention Hall, Philadelphia May 25-28

### JUNE

**Material Handling Institute,** 1959 Exposition Cleveland June 9-12

**Instrument Society of America,** Second International Symposium on Gas Chromatography, East Lansing, Mich. June 10-12

**UNESCO,** First International Conference on Information Processing, Paris, France June 13-31

**The Gordon Research Conferences,** Colby Junior College, New London, N. H. June 15-Sept. 4

**Instrument Society of America,** Second Nuclear Instrumentation Symposium, Idaho Falls, Idaho June 24-26

### JULY

**Case Institute of Technology,** Ten-Day Short Course on Numerical Feedback Control, conducted by Harry W. Mergler, Case Institute, Cleveland July 6-17


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**What the Control Engineer Should Know About Reliability,** April 1958, 8 pp. Not intended as a comprehensive treatise, but rather as a guide to aim the control engineer in the right direction, this staff-written article discusses the new concept of systems effectiveness, and briefly covers techniques for measuring reliability, predicting reliability, improving reliability, and costing reliability. Up to date reference sources increase the value. 20 cents.

**Survey of Numerically-Controlled Point-to-Point Positioning Systems,** 72 pp. This complete series covers 31 domestic and foreign systems. Detailed operational and performance characteristics of each system are discussed. Individual parts of series are also available as listed below. $1.50.

**Ready Reference Data Files—I,** 24 pp. A must for every control engineer's library. Includes the first 12 data files published in CONTROL ENGINEERING—a diversity of topics, from system reliability through the cost of industrial temperature-measuring systems. Each one gives a method of solving a particular problem. 50 cents.

**Servo Modulators—Their Application, Characteristics, and Availability,** 36 pp. A group of four integrated articles covering all phases of electromechanical, electronic, solid-state, and magnetic modulators. Typical circuit diagrams, characteristics, and applications are given for each type, plus an 84-item bibliography and tables listing commercial units. 65 cents.

**The Use of Digital Computers in Science, in Business, and in Control,** 112 pp. A collection of 14 articles published over a period of two years as the Digital Application Series. Prominent authorities cover the application, programming, overall system design, and commercial availability of digital computers in all phases of business, industry, and the military. $3.

**Analysis Instrumentation — II — Refractometers, Infrared Analyzers, Photometric Analyzers, Colorimetry,** 32 pp. This includes the second group of four articles of the Analysis Series. 60 cents.

**Analysis Instrumentation — I — Nuclear Magnetic Resonance, Chromatography, Radioactivity,** 32 pp. Reprint consists of first 4 articles of Analysis Instrumentation Series: a general introduction and detailed discussions of the three analysis techniques. Emphasis is on basic principles, practical tips, and the use of these techniques in automatic process control. 60 cents.

**Basic Data on Process Control,** 24 pp. A grouping of five articles on flow-process control, including: Basic Concepts of Feedback Control, Selecting Loops for Critical Control, Direct or Reverse Controller Actions, Modifying Valve Characteristics to Fit the Process, and Using Capacitance for Accurate Level Measurement. Practical information for every process control engineer. 50 cents.

**How to Simulate Dead Time,** 6 pp. Three tricky techniques for simulating dead time or transport lag. One's elec-

*Continued on Page 205*

tronic, another is pneumatic-mechanical, and the third uses magnetic tape. A useful reference for control engineers concerned with process simulation. 15 cents.

**Transistor and Thyratron Power Amplifiers,** 28 pp. These three articles—one on transistors and two on thyratrons—were prompted by the increasing control application of transistors as low-power amplifiers and thyratrons as high-power amplifiers. In each case the emphasis is on practical application, circuit design, system stabilization, etc. 50 cents.

**Static Switching Devices—New Tools for Industrial Control,** May 1957, 28 pp. An independent consultant analyzes the complete field of industrial static-switching systems. Starting off with a review of basic switching logic, he covers circuit characteristics of the fundamental devices, commercially-available systems, actual applications, etc. 50 cents.

**A Functional Analysis of Automatic Logging Systems,** February 1956, 16 pp. An examination of the various techniques and equipment used in performing the eight functions in a generalized automatic logging system: transducing, scale-factor correction and linearizing, derivation of quantities, scanning, analog-to-digital conversion, programming and control, alarm, and recording or logging. 50 cents.

**Automatic Machining—A View and a Preview,** 24 pp. A quick look at some of the newer techniques that are being used to control machine tools. It deals primarily with recorded-information (numerical) control, discussing ways to automatically furnish machining instructions, ways to drive the tool, or workpiece, and ways to measure position and size. 50 cents.

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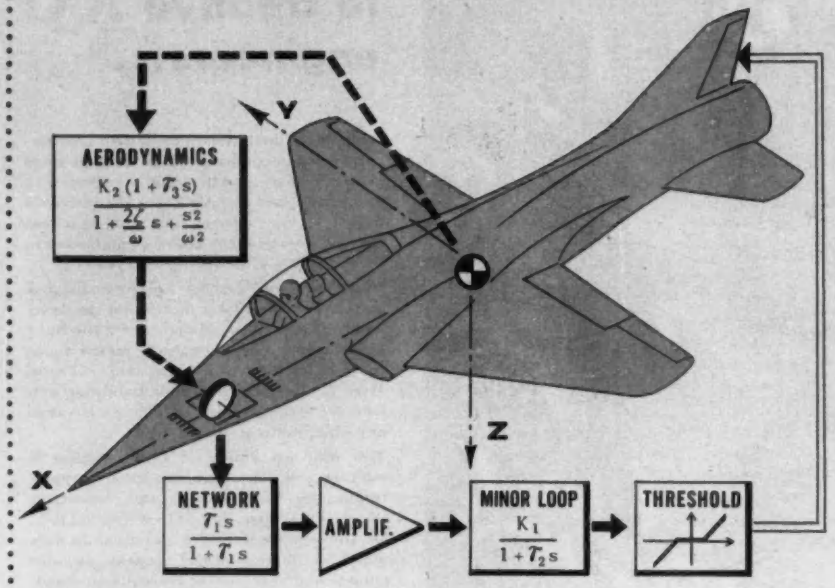


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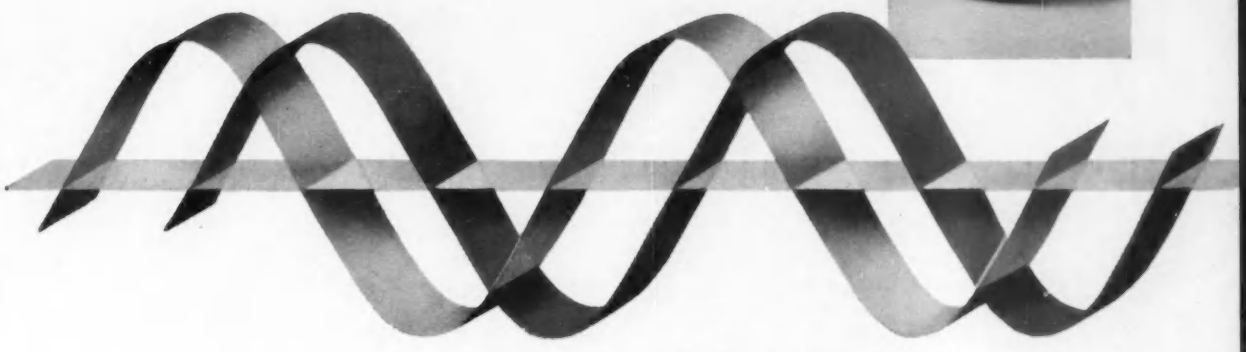
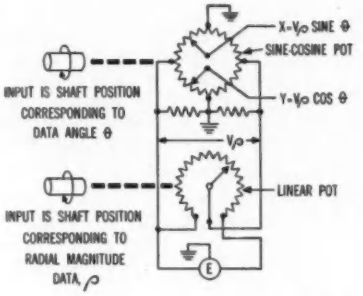
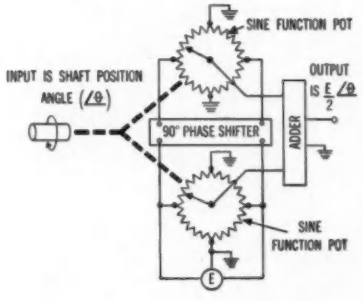
# SINE-COSINE
## *Precision*
## POTENTIOMETER-RESISTORS

**For resolution of voltage into sine and cosine components in accordance with positions of shaft rotation.**



### TYPICAL APPLICATIONS:




ANGLE DATA TRANSMISSION as used in automatic controls, directional and ranging systems, analog computers, and telemetry.

PHASE DIVISION as used in investigation of phase sensitive systems, delay measurements, and timing applications.

DATA CONVERSION as used in rotation of coordinates, or conversion from polar to rectangular coordinate form, for computers or data display applications.

Potentiometers having sinusoid functions are available in 3", 2", 1⅞", 1½", 1¼", and ⅞" diameters. These potentiometers are available with two sliders giving independent outputs, one proportional to the sine and the other to the cosine of the shaft angle. Multiple units may be ganged and phased for cosine function or for other applications such as rotation of coordinates.

Precision in potentiometer-resistors feature wide temperature range, excellent environmental stability, highly precise mechanical construction and electrical performance.

Technical reports on the use of these units, and complete data are available on request.

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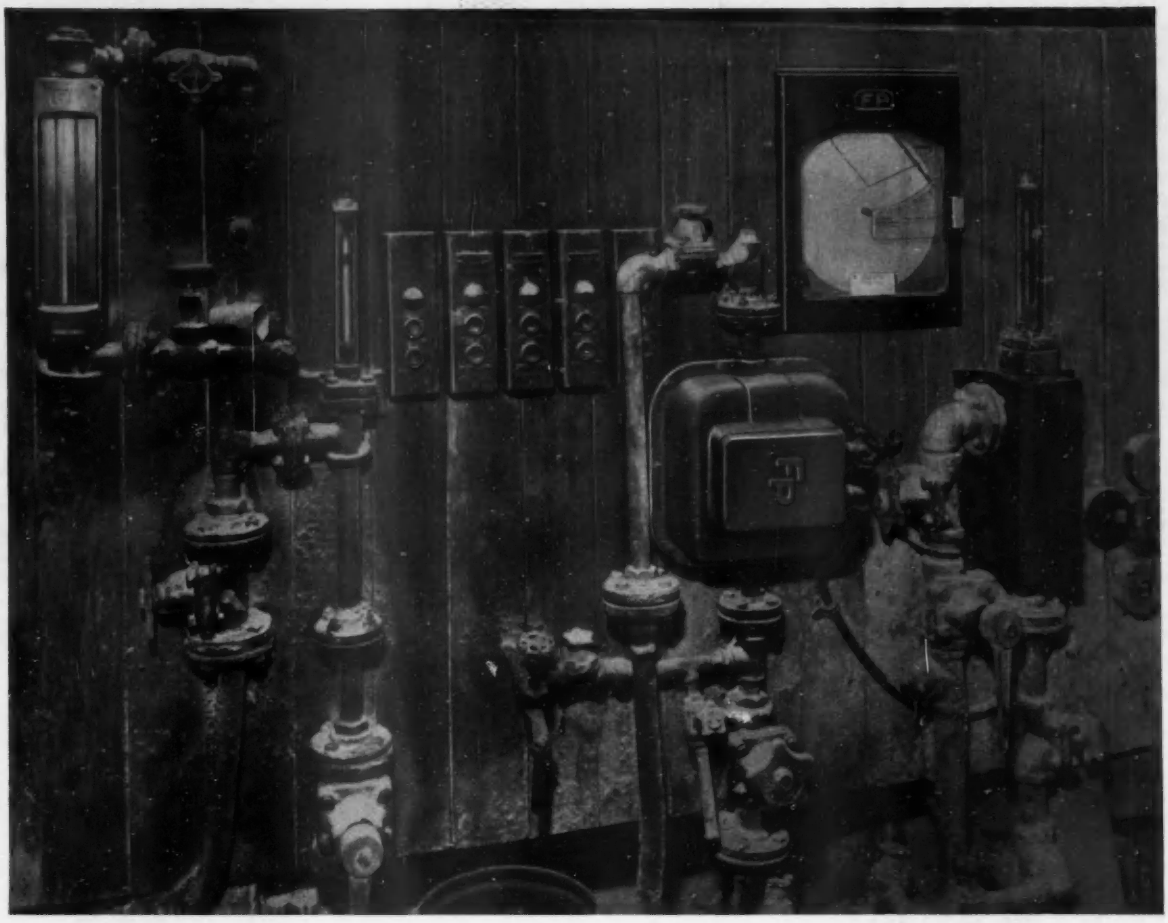
**CIRCLE 2 ON READER-SERVICE CARD**



*One-inch F&P magnetic flowmeter measures wet process phosphoric acid to an accuracy of better than ±1%, independent of viscosity, density, or piping configuration at Baltimore, Maryland plant of Fertilizer Manufacturing Cooperative.*

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